GENERAL REPORT

ON THE

PYKARA HYDRO-ELECTRIC DEVELOPMENT

PART I.—INTRODUCTION—HYDRAULIC

REVISED

MADRAS
PRINTED BY THE SUPERINTENDENT, GOVERNMENT PRESS

1928

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ON THE

PYKARA HYDRO-ELECTRIC DEVELOPMENT

PART I.—INTRODUCTION—HYDRAULIC

MAJOR H. G. HOWARD, M.C., MEM.A.I.E.E., M.AM.SOC.C.E.,
Chief Engineer.

REVISED

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1928

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First printing ... ... April 1928.
Second " (revised) ... ... June "

PART I—INTRODUCTION—HYDRAULIC.

SECTION

1. Introduction.
2. Hydrology.
3. Storage.
4. Hydraulic Works.
5. *Auxiliary and Construction* Plant.

With

Tables, Plans and Estimate.

PART I—INTRODUCTION—HYDRAULIC.

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PYKARA HYDRO-ELECTRIC DEVELOPMENT.

SECTION 1.—INTRODUCTION.

The possibility of developing power from the Pykara River has been recognized for some years, and reports and examinations by several engineers have been published from time to time. The first investigation, in any detail, appears to have been made in 1921 by Mr. B. D. Richards, M.I.C.E., of Messrs. Alfred Dickinson & Co., Consulting Engineers, who acquired the concession to utilize the waters of the Pykara and Avarai Halla Rivers for power purposes. The concession was afterwards purchased by the Power Securities Corporation, but was acquired back by Government in 1925. A more detailed study of the scheme was undertaken in 1925–26, under the direction of Mr. P. Hawkins, C.I.E., M.I.C.E., late Chief Engineer, Public Works Department, and copies of his report are available for reference.

The proposed works are located on the Nilgiri plateau about 15 miles from Ootacamund. Power is to be developed from the Pykara river, the catchment area of which is at an average elevation of 6,850 feet, and is 38 square miles in extent. The flow, though perennial, is very irregular and often drops to values around 20 cusecs during the dry season.

The Nilgiri plateau receives both the south-west and the north-east monsoons, but the run-off due to the south-west monsoon is very much higher than that due to the north-east. It is proposed to store as much of the south-west monsoon run-off as needed, and regulate the river accordingly.

Fortunately, the topography embraces a number of feasible storage sites so that the whole run-off of a low year can be stored if necessary. The ground at all the proposed dam sites is fairly good, but not very suitable for high structures. According to the report of a Government geologist, the rock belongs to the charnockite series and is a species of granite. Much of it, however, is badly fissured and disintegrated.

The country consists of undulating grassy downs, a small part of which is cultivated. There are a few patches of jungle. The catchment and works lie mostly in Government waste land or reserve forests, so that the cost of land for the scheme will be small.

Previous schemes contemplated the construction of dams varying in height from 164 feet up, forming reservoirs with capacities from 3,800 to 6,000 million cubic feet. At the proposed sites such structures would have been very costly owing to the poor foundations, while it is estimated that such large storages could not be fully utilized for several years.

The scheme as at present outlined consists of developing a series of smaller storage sites according to the power demand. The Glen Morgan stream will first be dammed, and sufficient water stored to ensure that the regulated river flow will take care of the power demands for about two years. At the end of this period a dam will be constructed across the Makurti river and another storage site developed to meet the increased power demand. When needed, other dams will be built to utilize the catchment up to the economical limit of regulated flow which, with the present information available, has been tentatively fixed at 150 cusecs, necessitating an effective storage of 3,100 million cubic feet.

This storage can eventually be provided by the construction of the Makurti, Porthimund, Sandy Nalla and Pykara dams. If the data now submitted on the hydrology of the catchment are found reasonably accurate, reservoirs will be provided in the order above named. Parson's Valley dam mentioned in the Introductory Report may not be needed. If Moyar is included, this will give a total capacity of 80,000 KW. or 106,000 H.P. for a maximum flow of 300 cusecs and 40,000 KW. or 53,000 H.P. for a continuous flow of 150 cusecs.

The regulated stream flow will be diverted by a low dam, built across the river three miles below the Pykara bridge into an aqueduct 6,840 feet in length.

This aqueduct has a capacity of 200 cusecs, and consists of both lined and unlined sections.

The water will be conveyed to a forebay located near the Pykara Falls Road. This forebay has a capacity of 65·63 million cubic feet, of which 53·5 million cubic feet is effective, and is formed by two earthen dams of heights 62 feet and 39 feet respectively, constructed at the ends of a natural depression.

The forebay will also be supplied with water from the Glen Morgan reservoir. This reservoir is to be formed by a masonry dam 45 feet high constructed at the outlet of the Glen Morgan stream, from a natural basin in the hills immediately south-east of the forebay.

The effective capacity of this reservoir is 26 million cubic feet, which is much below the run-off of the catchment. At a future date it is proposed to connect it with the Sandy Nalla reservoir by an aqueduct consisting of open canal and tunnel.

The Sandy Nalla stream has a catchment area of 17·3 square miles, and lies between Pykara and Ootacamund. A reservoir can be formed here by an inexpensive dam and a proportion of the run-off stored; this water together with any surplus run-off can be conveyed to the Glen Morgan reservoir and thence to the main forebay.

Two independent sources of water-supply will thus be available at some future date for the generation of power. This feature adds to the flexibility and value of the scheme.

From the forebay, water will be conveyed to a header through one—eventually two—riveted steel pipes about 1,000 feet long and 5 feet in diameter. At the head of these pipes an inlet tower will be constructed, and two sluice gates with screens and drainage valves installed. From this tower to the header the pipes are to be laid in the ground. At the header each 5 feet riveted pipe will be equipped with a surge chamber and will feed two 36 inches penstocks.

The penstocks will descend the northern slopes of the Nilgiri plateau for about 9,300 feet, falling some 3,100 feet in that distance. They vary in diameter from 36 inches at the top to 27 inches at the power-house. The velocities will be 10·6 feet for the first 1,350 feet, increasing to a maximum of 19 feet at the power-house for a capacity of 75 cusecs. Each line will be provided with an automatic butterfly valve, an air inlet, and a venturi meter at the header, and with a high pressure cylinder valve hydraulically operated, at the power-house.

An inclined haulage track for the transportation of workmen and material will parallel the penstocks.

The power-house is to be of steel and masonry, and will contain three 7,500 KW. generators to begin with. The complete installation proposed will consist of five 7,500 KW., and of two 15,000 KW. units.

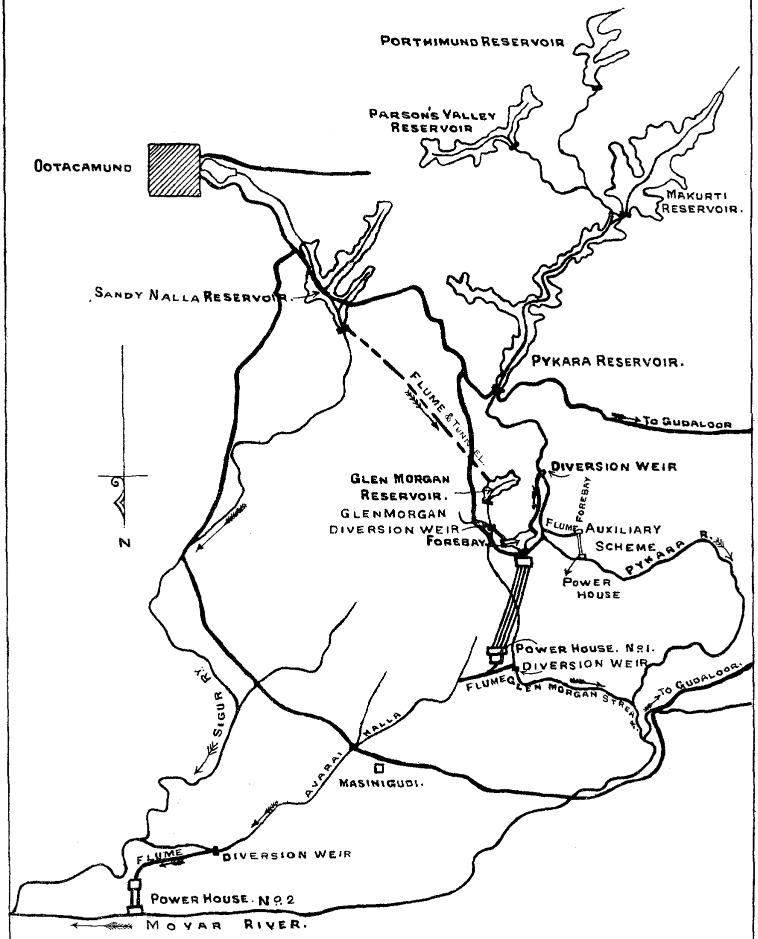
The same water used for the generation of power at Pykara can be utilized again in another scheme, known as the Moyar project.

The water will be conveyed from the tailrace through a short canal 6,800 feet long to the bed of the Avarai Halla stream and diverted 4·8 miles lower down into another canal about 2·5 miles long.

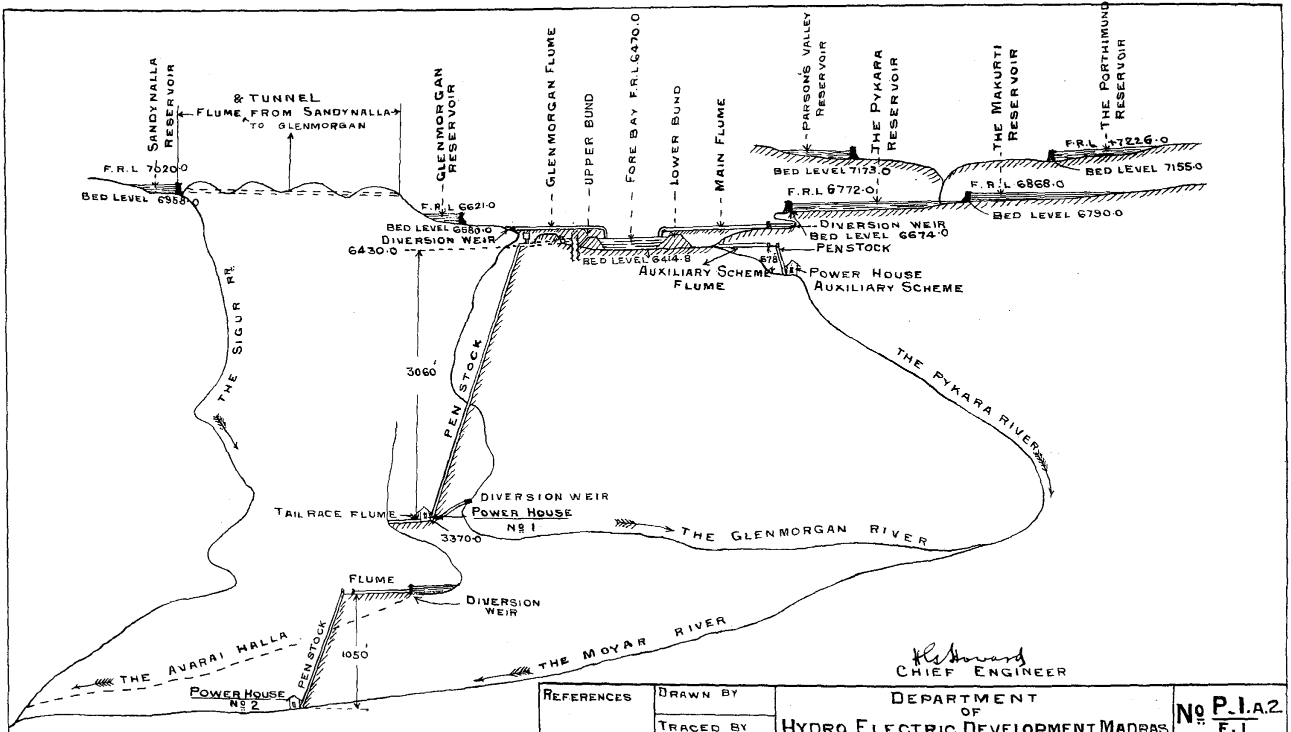
This canal leads to a forebay which will have to be constructed by excavation and lining. The capacity tentatively decided upon is 4 million cubic feet, which would be sufficient for a four hours' supply at peak load. With a continuous supply of 140 cusecs (it is assumed that about 10 cusecs will be lost by absorption between Pykara and Moyar) and a load factor of 50 per cent, a peak load of 20,000 KW. could be allowed.

From the forebay the water will be conveyed in two penstocks to the power plant situated at the bottom of the Mysore ditch.

The power plant would have a capacity of 20,000 KW., which might be increased later, if the present estimated run-off for the Pykara catchment is realized.



REFERENCES.	DRAWN. P.N. IYER. TRACED. P.P.	DEPARTMENT. OF HYDRO-ELECTRIC DEVELOPMENT, MADRAS.	No. P.I.A.I / F.1.
REVISIONS. OF P.I / F.I 2 11/27	CHECKED. P.N. IYER. APPROVED.	PYKARA. H. E. DEVELOPMENT.	SCALE: 1"=2 MILES.
		GENERAL SCHEME.	DATE ... 25. 5. 28.



REFERENCES	DRAWN BY	DEPARTMENT OF HYDRO ELECTRIC DEVELOPMENT MADRAS	No. P.I.A.2 / F.I
	TRACED BY M. DHANAKOTY		
REVISIONS	CHECKED BY P. N. IYER	PYKARA H. E. DEVELOPMENT	NOT TO SCALE
	APPROVED	PYKARA SCHEME PROFILE	DATE 30·4·28

A feature of this installation is the possibility of operating the plant by water from the Sandy Nalla reservoir via the Glen Morgan stream, which could be diverted near the Pykara power-house. This would render it independent of Pykara and be of value in case of any accident to the hydraulic works at the main installation.

Plan No. $\frac{P.-1\ A-1}{F.-1}$ gives a plan of the complete project, while plan No. $\frac{P.-1.\ A-2}{F.-1}$ shows the profile.

From the Pykara power-house the power will be conveyed by steel tower transmission lines to Coimbatore at 110,000 volts, which may be increased to 132,000 volts at a future date.

From Coimbatore other lines at 110,000, 66,000 and 11,000 volts will supply power to Tiruppur, Erode, Shoranur, Mettupalaiyam, Podanur, Pollachi, Anamalais, Palni, Dindigul, Trichinopoly, Madura and Virudhunagar—vide Drawing No. $\frac{P.-2\ A-1}{F.-1}$ in Part II.

At a later date, it is hoped to include Madras, Salem, Calicut, Cochin, Tanjore, and other districts, as shown in Drawing No. $\frac{P.-2.\ A-2}{F.-2}$ in Part II.

It is also expected to provide power for the electrification of the following sections of the South Indian Railway :—

Erode-Podanur-Shoranur-Mettupalaiyam-Nilgiris.
Dindigul-Podanur.
Trichinopoly-Madura.

Attention is drawn to the fact that Madras has been omitted for the present. There are no technical objections to the transmission of power from Pykara to Madras, although it would be by far the longest single transmission line in the world. Such a transmission system would create great interest in the engineering world, and draw attention to the industrial possibilities of the Presidency.

The construction of this line has not been advocated for the present, as it is not considered an economically feasible undertaking, but it may be in the near future.

An effort has been made in the load forecast and revenue returns, to exclude any data which may be termed speculative, so that the whole report may be characterized as conservative and the recommended policy as cautious.

The writer is, however, of the opinion that within ten years from now, or say, by the fifth year of operation, it may be found possible to include Madras in the transmission system.

With the advent of the electrification of the suburban lines of the South Indian Railway and the possibility of other local electrifications, and with only a nominal annual increase in the power sales of the Madras Electric Supply Corporation, the demand in the area should, in a few years, reach a figure which would render the construction of the lines to Madras and of the sub-station economically feasible.

An average rate of 0·5 anna per K.W.H. for bulk supply is considered the maximum figure at which hydro-electric power would prove attractive to Madras. At such a low rate very attractive tariffs could be offered to the local consumers, and no difficulty should be experienced in persuading the local mills and factories to electrify.

It is, however, difficult to interest the average industrial or business community in mere schemes. Once Pykara is a going concern, negotiations will be facilitated.

It has been estimated that as soon as the annual consumption of power around Madras reaches 60,000,000 K.W.H., it will be possible to link up that city with the main transmission system.

The Pykara power system has been so designed that such contingencies can be met at any time. It would merely involve the speeding up of the construction schedule.

Should hydro-electric power come to Madras, it would be advisable to enter into an agreement with the Madras Electric Supply Corporation for the use of their steam plant as a standby. Such facilities should not cost much, and in exchange their licence could be extended and other concessions allowed.

The electrification plans of the South Indian Railway are not yet definitely known; three programmes have been assumed as possible:—

Programme (*a*)—contemplates the transmission of power to the Nilgiris, Coimbatore and nearby towns, Madura, Dindigul, and Trichinopoly. The South Indian Railway are assumed to electrify—

(1) The Trichinopoly-Madura section by the first year of operation.

(2) The Dindigul-Podanur section by the fifth year.

(3) The Erode-Podanur-Shoranur-Mettupalaiyam and the Nilgiris sections by the eighth year.

Programme (*b*)—up to the fifth year power is to be transmitted only to the Coimbatore area. After the fifth year the transmission system is to be extended to Madura, Dindigul and Trichinopoly. The railway electrification programme assumed is—

(1) The Erode-Podanur-Shoranur-Mettupalaiyam and the Nilgiris sections by the first year.

(2) The Podanur-Dindigul section by the third year.

(3) The Trichinopoly-Madura section by the fifth year.

Programme (*c*)—assumes that the South Indian Railway will not electrify any of the main line sections, and contemplates the transmission and distribution of power only in the Nilgiris and the Coimbatore districts. It allows for 600 K.W. of railway demand either from the Erode and Podanur shops or from the electrification of the Nilgiri Railway.

Programmes (*a*) and (*b*) have been studied in some detail and are discussed in the following pages. *Programme* (*c*) involves a complete redesign of the electrical and mechanical features and, if found necessary, a supplementary report will be issued on it. Preliminary studies indicate that the scheme can be so designed as to fall within the Public Works Department interpretation of a productive work.

Of the three programmes mentioned (*b*) appears the most attractive at the outset. There is less idle capital invested at one time on transmission lines and sub-stations, while the development of the power market can proceed parallel with railway electrification.

It will, however, be shown in Part III of the report, that programme (*a*) is actually the better one and gives a higher return eventually.

The total costs of the works are estimated as follows:—

	First year of operation.	Tenth year of operation.	Full development.
	RS.	RS.	RS.
Programme (*a*)	2,07,75,400	2,91,85,900	6,71,55,900
Programme (*b*)	1,77,58,400	2,91,65,500	6,71,35,500

These estimates are lower than those given in the Introductory Report. In addition to certain modifications in the original design, the estimates have been influenced a good deal by information on costs and construction methods in India kindly furnished by Mr. S. G. Forbes, Chief Electrical Engineer to the Mysore Government, and Messrs. H. P. Gibbs and N. J. Cursetjee, Director and Chief Engineer respectively of the Tata Engineering Company. When compiling the Introductory Report the writer had to rely mainly on the costs, etc., of similar works in the West which, in most cases, were higher.

All schemes more than satisfy the conditions of a productive public work as laid down by Government. The returns on the investment at the end of the tenth year are 9·7 per cent and 7·53 per cent on programmes (*a*) and (*b*) respectively with 6 per cent rate of interest. With 5 per cent rate, the corresponding figures for returns are 9·89 per cent and 8·04 per cent respectively. The lower returns are due to the fact that a higher contribution to the depreciation fund is necessary when 5 per cent interest is allowed. The actual financial position is, however, much more favourable than it appears, as the surplus available when 5 per cent interest is charged is much higher than when 6 per cent is allowed—vide financial results, Part III, page 24.

As regards the estimates, it is believed that ample provision has been made, and that the total cost will not be exceeded. They have been roughly checked by comparison with similar and finished works elsewhere, after making due allowance for local conditions.

The forecast of load and revenue is considered quite safe, and if statistics of similar districts elsewhere, particularly Bangalore, are referred to, the Pykara figures will be found conservative.

In concluding this introduction, it may not be out of place to give an extract from a letter to the writer from a well-known engineer who has been responsible for the development of hydro-electric power on a large scale in India :—

> "The industrial development of India is very much behind what it ought to be, and the result is amazing when a reliable supply of power is made available at economic values. If there is no supply of a certain commodity, the demand is either entirely absent or is very much below what it ought to be ; consequently, when a supply is made available at economic values, the demand is automatically produced and the result will be really astonishing . . . Government can invest its money for the supply of power to small villages and hamlets which, at first, do not have any indication of a demand for power in paying quantities, but as soon as a supply is made available, the demand follows and the consumption will be in sufficient quantities to pay a net return on the investment and make of it a productive undertaking."

This has also been the writer's experience, particularly in the more recently developed countries in South America.

For reasons of economy and convenience, the report has been divided into five parts as follows :—

Part I—Introduction—Hydraulic.
Part II—Electrical and Mechanical.
Part III—Financial.
Part IV—Specifications.
Part V—Lay-out drawings and detailed estimates.

Parts I, II and III will form the main report for general examination and scrutiny. Parts IV and V will contain details of design, working drawings, and specifications for all the structures, machinery, etc. Much of this work has already been completed, but a part of it can only be decided upon after additional information has been received from the manufacturers of the various machinery and equipment.

In the preparation of this report the writer has been ably assisted by the staff of the department.

Lieut.-Col. M. G. Platts, M.I.C.E., and Mr. P. Natesa Ayyar, B.A., have been mainly responsible for the designs and details of the hydraulic structures, also the section on hydrology, while the greater part of the field work has been carried out under the direction of Mr. N. Krishnamurti, B.E.

The calculations and diagrams necessary in the design and estimates of the electrical and mechanical section were worked out by Mr. G. Sundaram, M.A., and Mr. M. Subramanian, B.E.; they also prepared the curves and tables for the financial section, and generally assisted in editing the report.

April 1928. H. G. HOWARD.

Since the first issue of this report certain plans and tables have been revised with corresponding changes in the text.

June 1928. H.G.H.

SECTION 2.—HYDROLOGY.

In the Introductory Report attention was drawn to the fact that the run-off for the minimum year, as deduced, appeared high when compared with the rainfall records and other reports—the most marked differences appearing in the figures given for the flow during the south-west monsoon—although the river had been gauged for three years. It was evident that, either the rainfall records taken and deduced were incorrect, or the gaugings were not reliable.

For the purposes of this report it was decided that a fresh study of the hydrology of the Pykara catchment be made and a further analysis undertaken of all the records of rainfall and run-off available.

It is always risky to attempt to deduce the run-off of any catchment by formulæ or from the records of other catchments. If however reliable rainfall records for the catchment under study are available, and records of both rainfall and run-off of adjoining catchments have been kept, it should be possible to devise a method of analysis, whereby a logical deduction of the stream-flow over a period of years can be obtained.

In the following paragraphs a method of arriving at the run-off of the Pykara catchment over a series of years has been worked out by the Civil Engineering *Division*. The rainfall records at Pykara are taken as practically accurate, while the run-off is obtained by taking the mean of the run-offs of two catchments having similar natural features to that of Pykara and lying on each side of the Pykara catchment.

Rainfall.—Rain-gauges in or near the catchment are situated as shown in plan $\frac{P\text{-}29}{F\text{-}1}$ with the period of record noted against each.

The year has been divided into three seasons, viz. :—

Summer—January to May inclusive.
South-west monsoon—June to September inclusive.
North-east monsoon—October, November and December.

An examination of the seasonal rainfalls at the various stations shows that the Pykara gauge indicates the average conditions over the catchment more closely than any of the others. This gauge has therefore been taken as showing the proportionate annual variations on the whole catchment.

The records show that with the exception of the Avalanche gauge the rainfalls at the stations vary very little during the summer and north-east monsoon seasons and that most of the annual variation which occurs is due to differences in the south-west monsoon.

The average monthly rainfall over each of the basins concerned has been arrived at as follows :—

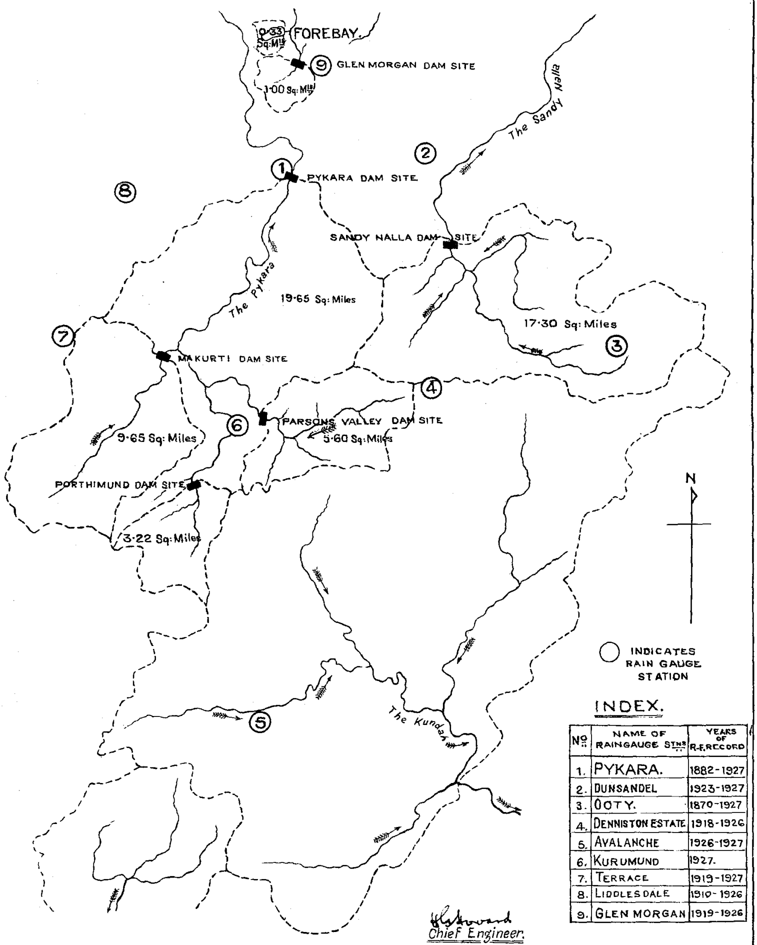
Table I shows the records on the Pykara gauge divided into seasons.

Table II shows the average readings of the gauges in and surrounding the catchment and the ratios of their seasonal rainfalls to those of Pykara for the corresponding periods. Plan $\frac{P\text{-}30}{F\text{-}1}$ shows rainfall ratio contours on the catchments for the three seasons drawn from and in terms of the ratios in Table II.

The averages of these contours are shown as catchment and seasonal factors and are abstracted in Table III.

The product of the appropriate factor and the seasonal rainfall as measured on the Pykara gauge thus gives the average rainfall on the catchment concerned for the particular season under consideration.

The monthly average rainfalls over the whole Pykara basin thus deduced are shown in Table IV and have been arrived at by multiplying the monthly rainfalls at Pykara by the factor shown in Table III for the catchment concerned and for the season under which the individual month is included.

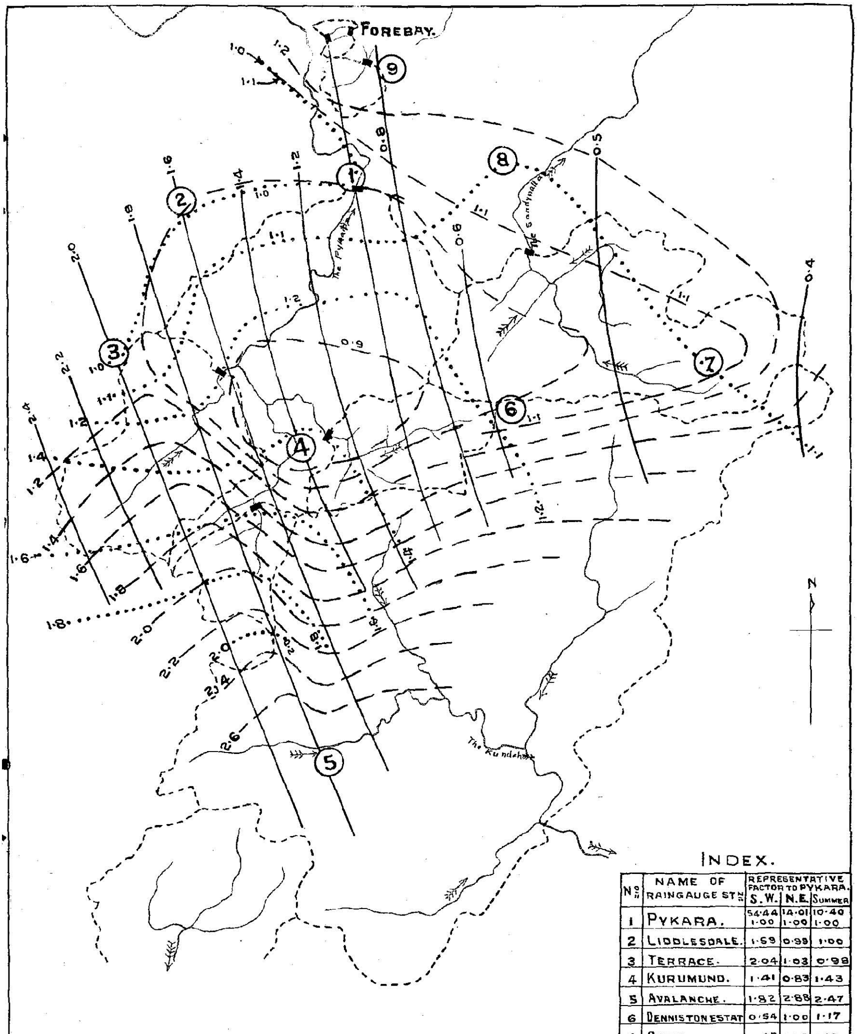


INDEX.

No.	NAME OF RAINGAUGE STNS	YEARS OF R.F. RECORD
1.	PYKARA.	1882-1927
2.	DUNSANDEL	1923-1927
3.	OOTY.	1870-1927
4.	DENNISTON ESTATE	1918-1926
5.	AVALANCHE	1926-1927
6.	KURUMUND	1927.
7.	TERRACE	1919-1927
8.	LIDDLESDALE	1910-1926
9.	GLEN MORGAN	1919-1926

Chief Engineer.

REFERENCES	DRAWN BY	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT	No P.29 F.1.	
	TRACED BY	PYKARA H.E DEVELOPMENT	SCALE 2 MILES = 1 INCH	
REVISIONS	CHECKED BY P.N. Iyer	BASIN MAP OF		
	APPROVED BY	PYKARA & SANDY NALLA	DATE. 2-5-28.	



INDEX.

No.	NAME OF RAINGAUGE STN.	REPRESENTATIVE FACTOR TO PYKARA. S.W.	N.E.	SUMMER
1	PYKARA.	54·44 1·00	14·01 1·00	10·40 1·00
2	LIDDLESDALE.	1·59	0·99	1·00
3	TERRACE.	2·04	1·03	0·98
4	KURUMUND.	1·41	0·83	1·43
5	AVALANCHE.	1·82	2·88	2·47
6	DENNISTON ESTAT	0·54	1·00	1·17
7	OOTY.	0·45	1·05	1·10
8	DUNSANDAL.	0·54	1·12	1·10
9	GLEN MORGAN	0·79	1·28	1·20

DAMSITES
S.W. MONSOON CONTOUR LINES.
N.E. ,, ,,
SUMMER ,, ,,
IN RED. WATERSHED LINES.
BLUE. STREAM COURSE.
RAINGAUGE STATION.

CHIEF ENGINEER

REFERENCES.	DRAWN BY,	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS.	No. P.30 / F.1
	TRACED BY, P. PARAMASIVAN.	PYKARA H.E. DEVELOPMENT.	SCALE. 2 MILES = 1 INCH.
REVISIONS.	CHECKED BY, P.N. IYER.	PRECIPITATION RATIO CURVES OF PYKARA & SANDYNALLA	
	APPROVED BY, 5-4/28		DATE:- 21·2·28.

Table I.

Rainfall at Pykara.

(In inches.)

Year.	January to May (dry).	June to September (south-west).	October to December (north-east).	Total for the year.	Year.	January to May (dry).	June to September (south-west).	October to December (north-east).	Total for the year.
1882	9·42	102·31	18·36	130·09	1908	10·06	41·09	10·58	61·73
1883	8·14	45·80	12·91	66·85	1909	24·49	50·84	14·34	89·67
1884	10·08	43·20	30·20	83·48	1910	7·61	54·94	16·52	79·07
1885	6·85	42·37	26·17	75·39	1911	9·08	66·49	13·14	88·71
1886	14·95	53·03	6·29	74·27	1912	5·51	46·19	11·05	62·75
1887	12·07	36·93	22·48	71·48	1913	6·67	44·33	14·96	65·96
1888	11·59	34·74	8·17	54·50	1914	6·04	66·29	11·56	83·89
1889	12·76	50·63	15·29	78·68	1915	9·98	55·46	12·40	77·84
1890	12·43	28·57	8·84	49·84	1916	9·22	45·33	11·85	66·40
1891	9·22	39·87	13·73	62·82	1917	6·11	34·70	15·57	56·38
1892	9·62	37·39	8·07	55·08	1918	10·86	14·70	20·72	46·28
1893	9·91	44·22	19·36	73·49	1919	8·85	56·63	13·23	78·71
1894	10·36	39·40	14·21	63·97	1920	13·59	73·51	12·32	99·42
1895	11·62	47·62	15·26	74·50	1921	8·93	83·58	11·04	103·55
1896	2·75	87·02	12·11	101·88	1922	7·35	48·27	20·06	75·68
1897		Temporarily closed.			1923	10·49	78·62	10·08	99·19
1898	9·83	47·18	16·95	73·96	1924	9·47	104·37	13·11	126·95
1899	14·25	29·60	5·06	48·91	1925	11·72	47·93	12·51	72·16
1900	13·29	76·29	11·52	101·10	1926	8·79	54·84	7·24	70·87
1901	15·93	53·28	22·51	91·72	1927	5·57	56·36	6·17	68·10
1902	14·10	57·52	19·22	90·84					
1903	16·10	75·34	20·86	112·30					
1904	14·85	65·31	5·73	85·89	Total for 45 years.	467·90	2,449·63	630·41	3,547·94
1905	12·69	54·83	12·87	80·39					
1906	6·22	65·65	11·90	83·77					
1907	8·48	67·06	13·89	89·43	Average ..	10·40	54·44	14·01	78·85

Table II.

Average readings of surrounding rain gauges.

Gauge.	Period.	Years.	Average rainfall in inches.				Average rainfall in inches at Pykara for same period.				Ratios.			
			Summer.	South-west monsoon.	North-east monsoon.	Total.	Summer.	South-west monsoon.	North-east monsoon.	Total.	Summer.	South-west monsoon.	North-east monsoon.	Total.
1. Pykara ..	1882–1927	45	10·40	54·44	14·01	78·85	..	..	..	..	..	..	..	..
2. Liddiesdale ..	1910–26	17	8·87	91·31	13·20	113·38	8·84	57·43	13·37	79·64	1·00	1·59	0·99	1·42
3. Terrace ..	1919–27	9	9·19	137·05	12·05	158·29	9·42	67·12	11·75	88·29	0·98	2·04	1·03	1·79
4. Krurmund ..	1927	1	7·99	79·54	5·10	92·63	5·57	56·36	6·17	68·10	1·43	1·41	0·83	1·36
5. Avalanche ..	1926–27	2	17·74	101·18	19·35	138·27	7·18	55·60	6·71	69·49	2·47	1·82	2·88	1·99
6. Nanjanad ..	1918–26	9	11·69	33·81	13·42	58·92	10·01	62·49	13·37	85·87	1·17	0·54	1·00	0·69
7. Dunsandle ..	1923–27	5	10·09	37·04	11·00	58·13	9·21	68·42	9·82	87·45	1·10	0·54	1·12	0·66
8. Ootacamund ..	1870–1927	58	11·59	24·20	14·78	50·57	10·40	54·44*	14·01	78·85	1·10	0·45	1·05	0·64
9. Glen Morgan.	1919–26	8	11·78	53·77	15·97	81·52	9·90	68·47	12·45	90·82	1·20	0·79	1·28	0·90

* Average of 45 years.

Table III.

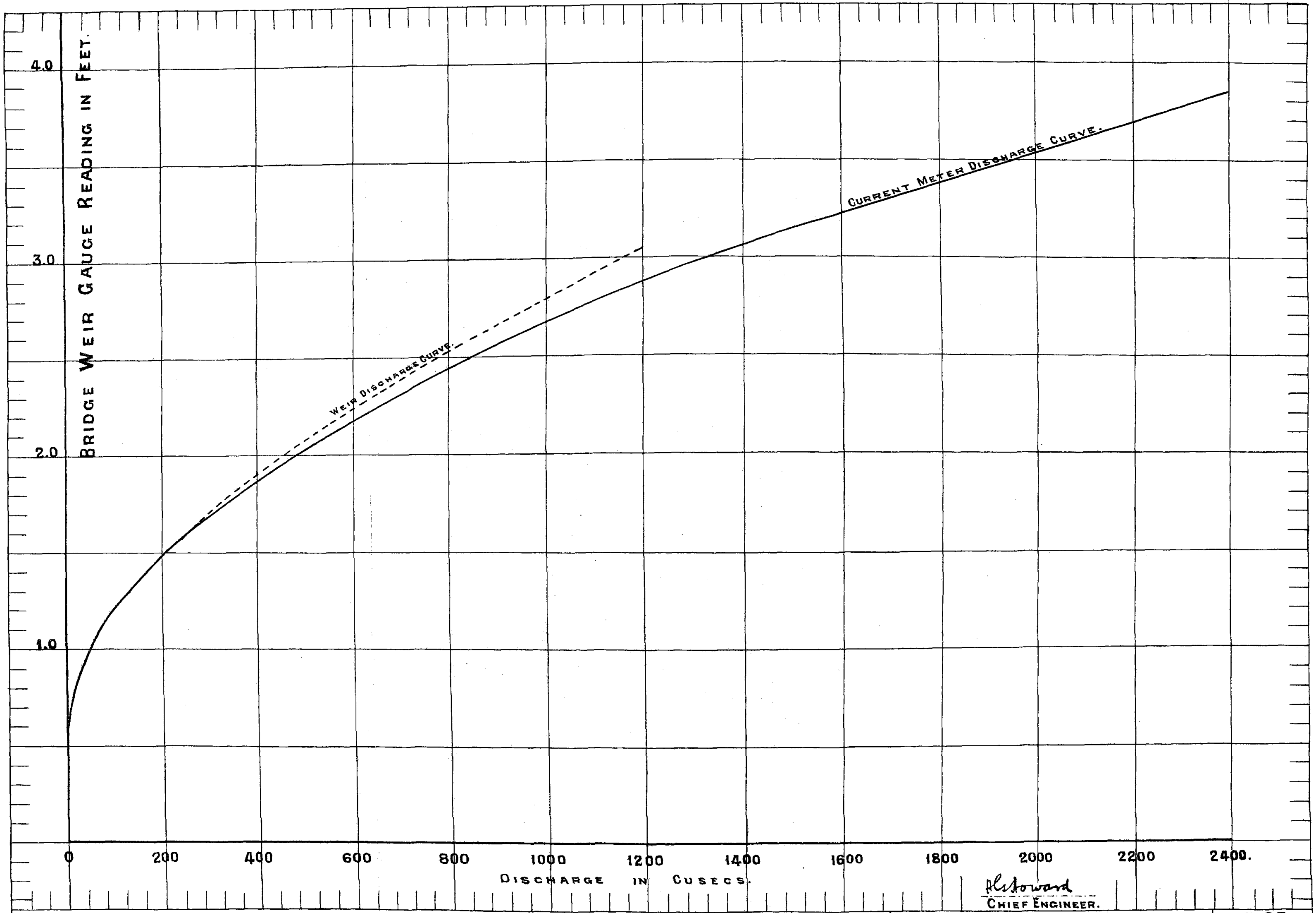
Factors by which the seasonal rainfall at Pykara must be multiplied to give the average seasonal rainfalls on the different basins in the scheme as computed from the Iso-hyetal map of Pykara basin—Plan No. $\frac{P.\ 30}{F.\ 1}$.

	Pykara whole basin.	Pykara free basin.	Makurti basin.	Porthimund basin.	Parsons valley basin.	Glen Morgan basin.	Sandy Nalla basin.
Catchment area in square miles ..	38·12	19·65	9·65	3·22	5·60	1·00	17·30
Seasons.							
Summer	1·34	1·25	1·34	1·77	1·34	1·20	1·12
South-west monsoon..	1·45	1·25	1·98	1·86	1·05	0·92	0·50
North-east monsoon..	1·15	0·97	1·31	1·88	1·03	1·24	1·09
Whole year	1·38	1·20	1·78	1·85	1·03	1·01	0·69

Table IV.

Computed monthly rainfall and run-off in inches for Pykara Basin, Period, 1882—1927.

Year.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Total rainfall, April to March in inches.	Total run-off, April to March in inches.
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)
1882 ..	1·8	..	..	..	1·3	..	0·6	0·8	8·9	1·5	38·9	23·6	75·6	63·5	19·4	16·9	14·5	15·0	12·7	11·8	8·4	9·2	..	1·2	180·9	146·8
1883 ..	0·3	1·0	0·2	1·1	1·4	1·2	5·5	1·4	3·5	0·8	16·1	9·7	24·4	19·0	25·5	19·7	0·4	1·0	5·8	4·3	6·4	6·4	2·6	2·6	90·2	65·3
1884 ..	..	0·1	..	0·5	..	— 0·2	3·7	1·2	9·8	2·0	7·8	6·4	16·6	12·3	28·7	21·9	9·6	8·5	22·7	18·8	7·4	7·6	4·7	4·6	112·7	85·5
1885 ..	..	0·3	..	0·6	1·7	1·3	3·8	1·2	3·6	0·6	15·6	8·8	31·8	24·5	8·9	6·3	5·1	4·7	13·0	10·3	13·1	12·3	4·0	3·9	99·0	73·2
1886 ..	..	0·2	..	0·5	0·1	— 0·1	1·8	0·9	18·2	4·3	12·4	11·1	31·0	25·5	21·8	17·1	11·6	10·8	3·6	2·7	3·3	5·2	0·3	— 0·5	106·9	80·3
1887 ..	..	0·2	0·3	0·9	2·6	2·1	9·4	2·0	3·9	1·4	20·3	13·6	18·4	15·9	4·2	2·4	10·6	9·1	13·1	10·3	9·8	9·4	3·0	3·0	92·8	67·6
1888 ..	0·1	0·2	..	0·6	..	— 0·3	4·4	1·3	11·0	2·6	13·0	10·0	14·4	11·8	14·9	10·8	8·0	9·9	1·4	0·3	4·4	4·5	3·5	3·2	76·7	53·2
1889 ..	..	0·1	..	0·4	1·7	1·3	5·6	1·4	9·8	2·5	15·2	11·3	22·6	18·6	19·6	15·0	16·1	14·2	12·8	10·6	2·9	8·6	1·8	2·0	111·1	84·1
1890 ..	1·0	1·2	0·1	0·6	3·6	3·1	6·3	1·5	5·8	1·5	11·1	7·7	13·5	10·2	10·4	7·0	6·4	5·3	7·0	4·8	2·3	2·6	0·8	0·7	64·6	42·3
1891 ..	0·2	0·2	0·8	0·5	..	0·3	3·6	1·2	7·7	1·6	9·4	6·4	37·2	28·3	9·6	7·0	1·6	1·8	11·9	9·4	1·7	2·3	2·1	2·1	85·4	61·0
1892 ..	..	0·1	0·3	0·8	0·3	..	5·5	1·4	6·8	1·7	7·8	5·8	27·6	20·6	14·1	10·3	4·7	4·3	6·0	4·2	1·6	2·2	1·7	1·7	78·7	55·0
1893 ..	..	..	0·7	1·1	2·2	1·7	1·3	0·8	9·1	1·8	14·7	12·3	19·2	15·9	15·5	11·5	9·7	8·6	15·2	12·3	7·1	7·1	..	0·4	99·9	74·0
1894 ..	..	0·2	0·3	0·8	2·8	2·3	5·4	1·4	5·3	1·3	10·0	6·5	22·1	16·5	18·9	14·3	6·1	5·2	14·6	11·7	1·8	2·4	..	0·4	84·2	59·9
1895 ..	..	..	..	0·5	..	— 0·3	9·0	1·9	6·6	2·1	26·8	18·3	18·6	17·7	20·2	15·6	3·5	4·0	14·0	11·4	2·1	2·8	1·4	1·7	102·2	76·0
1896 ..	..	0·2	..	0·6	..	— 0·3	0·6	0·8	3·1	..	42·3	23·6	44·3	38·6	20·1	16·4	19·5	18·2	4·2	4·0	4·5	5·3	5·2	5·4	148·7	117·9
1897 ..	..	0·6	3·9	4·2	1·0	0·8	3·5	1·2	9·6		30·2	19·0	Temporarily closed.								1·4	..	1·7	..	..	..
1898 ..	..	..	0·4	..	..	..	6·1	1·5	0·7	1·7	16·9	11·4	25·9	21·1	11·3	8·3	14·4	12·6	11·9	9·6	7·6	7·6	..	0·5	101·1	75·1
1899 ..	..	0·2	0·3	0·8	..	— 0·2	11·7	2·3	7·2	2·6	10·4	9·5	12·8	10·8	6·1	3·6	13·6	11·3	5·0	3·3	0·5	1·1	0·3	0·4	68·2	45·5
1900 ..	0·5	0·8	..	..	0·1	— 0·2	4·8	1·3	12·5	3·1	18·5	13·9	33·4	28·1	40·1	32·1	18·6	17·5	11·4	10·1	1·0	2·3	0·8	1·5	147·0	116·3
1901 ..	0·7	1·2	3·7	4·0	1·5	1·2	5·0	1·4	10·4	2·5	21·2	14·9	24·0	20·9	9·3	6·7	22·8	19·8	15·8	13·3	6·5	6·8	3·6	3·7	122·9	94·7
1902 ..	0·6	0·9	0·1	0·5	3·6	3·3	5·0	1·4	9·7	2·3	8·8	7·2	48·2	37·3	8·5	6·6	17·8	15·9	12·2	10·2	2·8	3·6	7·4	7·1	120·6	92·6
1903 ..	0·1	0·5	0·1	0·7	..	— 0·2	0·9	0·8	20·5	4·7	14·9	13·1	55·9	45·9	18·2	14·9	20·3	18·9	6·3	5·8	13·6	13·3	4·1	4·6	155·3	123·8
1904 ..	0·3	0·9	..	0·7	0·3	0·2	4·6	1·3	14·7	3·7	38·7	26·5	29·7	29·4	16·2	13·1	10·2	10·2	5·3	5·4	1·0	1·3	0·2	0·8	124·5	96·1
1905 ..	..	0·4	1·0	1·5	2·9	2·4	3·3	1·1	9·7	2·2	21·3	14·1	26·3	22·3	12·9	9·7	19·0	16·7	12·5	10·3	2·3	3·1	..	0·5	111·0	84·0
1906 ..	3·3	3·2	0·1	0·7	0·3	0·1	0·5	0·7	4·1	0·3	17·3	9·0	36·7	28·1	25·8	20·2	15·4	13·9	7·6	6·3	3·0	3·7	3·1	3·3	116·0	88·5
1907 ..	..	0·3	..	0·6	2·5	2·1	2·2	1·0	6·6	1·1	15·8	9·5	29·9	23·3	34·4	27·0	17·2	15·6	10·8	9·2	3·3	4·1	1·9	2·3	123·4	95·1
1908 ..	..	0·4	0·2	0·8	1·1	0·8	2·5	1·0	9·6	2·0	11·1	7·7	30·5	23·5	16·2	12·2	1·8	2·1	10·6	8·3	0·7	1·5	0·8	1·1	93·6	68·4
1909 ..	9·8	8·9	..	0·5	..	— 0·2	4·7	1·3	18·3	4·7	19·1	16·1	28·4	25·3	16·7	13·0	9·6	9·2	9·7	8·0	6·8	7·1	..	0·6	114·6	87·2
1910 ..	..	0·3	1·0	1·5	0·4	0·1	1·2	0·8	7·6	1·3	10·4	6·2	34·4	25·8	22·9	17·7	11·9	10·8	12·8	10·5	6·2	6·5	.	0·5	109·1	82·3
1911 ..	..	0·3	0·3	0·8	1·4	1·1	2·3	1·0	8·2	1·6	41·6	25·5	39·4	35·8	7·6	6·3	7·9	8·1	7·3	5·2	2·5	4·3	5·3	5·3	122·8	94·6
1912 ..	..	0·2	..	0·6	0·7	0·5	3·1	1·1	3·5	0·4	14·9	8·2	23·4	17·7	20·2	15·1	8·5	7·6	9·3	7·2	3·3	3·8	0·1	0·3	87·1	62·5
1913 ..	..	0·2	..	0·4	0·8	0·5	2·7	1·0	5·5	1·0	8·0	4·5	36·3	26·8	7·4	5·0	8·6	7·5	8·5	6·4	4·5	4·8	4·2	3·9	86·2	61·7
1914 ..	..	0·1	..	0·5	0·5	0·2	1·0	0·8	6·6	1·0	13·8	7·9	53·0	40·8	20·3	16·1	9·0	8·9	9·5	8·0	1·9	2·9	1·9	2·2	118·6	90·8
1915 ..	1·0	1·2	..	0·7	0·6	0·3	3·7	1·2	8·1	1·7	31·9	20·1	24·2	22·4	10·4	7·9	14·0	12·6	7·1	5·7	6·5	6·7	0·6	1·0	106·5	79·9
1916 ..	..	0·3	..	0·6	..	— 0·3	1·6	0·9	10·8	2·2	23·7	15·4	10·7	10·3	19·6	14·8	11·8	10·4	8·8	6·9	3·8	4·2	1·1	1·3	93·8	68·5
1917 ..	0·1	0·3	1·4	1·7	0·4	0·1	1·3	0·9	5·0	0·6	12·3	6·5	9·0	5·8	11·2	7·3	17·8	14·6	7·5	5·4	8·7	8·2	1·7	1·7	76·3	52·8
1918 ..	1·7	1·6	..	0·4	0·1	— 0·2	3·2	1·1	9·6	2·1	3·3	3·3	5·3	2·4	10·9	6·9	1·8	1·0	4·4	2·2	16·0	14·3	3·5	3·2	60·0	38·2
1919 ..	1·1	0·9	0·8	1·1	0·1	— 0·2	5·1	1·4	4·8	1·0	20·9	12·9	35·3	28·7	16·5	12·7	9·5	9·0	5·1	4·3	9·6	9·4	0·5	1·0	112·8	85·6
1920 ..	5·1	4·8	..	0·6	..	— 0·2	10·0	2·1	3·1	1·1	63·5	39·6	25·4	29·4	7·8	6·7	9·8	10·0	6·8	6·0	7·4	7·8	..	0·8	134·4	105·0
1921 ..	0·6	2·0	..	0·7	..	— 0·2	6·1	1·5	5·3	1·3	9·2	6·4	71·6	55·3	29·6	24·2	10·8	11·2	9·6	8·6	2·4	3·7	0·7	1·5	145·5	115·0
1922 ..	0·1	0·6	..	0·7	0·1	..	1·0	0·8	8·7	1·6	10·8	5·7	31·6	24·9	19·4	14·7	8·1	7·5	11·6	9·3	9·4	9·2	2·1	2·3	105·6	79·1
1923 ..	0·1	0·3	..	0·6	2·8	2·2	5·9	1·5	5·2	1·3	6·7	4·7	52·6	39·9	48·2	38·7	6·5	7·5	9·3	8·2	1·7	2·9	0·6	1·4	138·1	108·3
1924 ..	0·5	0·9	..	0·7	0·9	0·6	3·7	1·2	7·6	1·6	21·3	13·6	103·1	82·2	14·6	13·4	12·3	13·2	7·9	7·8	5·8	6·9	1·4	2·5	178·5	144·6
1925 ..	0·6	1·2	..	1·0	0·2	..	5·3	1·4	9·5	2·4	14·6	10·7	23·6	19·2	21·5	16·5	9·8	8·9	5·7	4·4	4·9	5·2	3·8	3·7	102·7	76·5
1926 ..	2·5	2·5	..	0·5	1·5	1·1	2·2	1·0	5·5	0·8	5·4	2·9	34·5	24·8	27·8	21·4	11·8	10·7	4·1	3·0	3·4	3·9	0·9	1·2	96·2	70·7
1927 ..	0·2	0·3	0·1	0·6	0·3	0·1	2·9	1·1	3·8	0·5	25·0	14·2	38·9	31·7	10·6	8·1	7·2	7·0	2·9	2·0	4·0	4·4	0·2	0·6	..	..



Chief Engineer.

References.	Drawn By,	Department of Hydro-Electric Development, Madras.	No. P. 35. / F.2.
	Traced By, P. Paramasivan.	Pykara H. E. Development.	Scale:- As in chart.
Revisions.	Checked By, P.N. Iyer.		
	Approved By,	Discharge Curves - Pykara River	Date:- 4-5-1928.

Run-off.—River flow records.—Flow records are available for the whole of the three years 1925, 1926 and 1927, but only for the dry weather periods of the years 1915, 1916, 1917 and 1919 to 1923.

There is a rectangular notched weir across the Pykara at the site of the old bridge, and an automatic water stage recorder which has been in service for the three years, 1925, 1926 and 1927. This weir measures flows up to about 750 cusecs with a reasonable degree of accuracy.

Higher rates of flow during the monsoon floods have been computed from three series of gauging operations conducted in 1925, 1926 and 1927. A discharge curve plan $\frac{P\text{-}35}{F\text{-}2}$ has been drawn with these observations correlated to the gauge at the weir, and the monthly flow for the three-year period 1925 to 1927 calculated from it.

The rainfall on the catchment computed as described above compares with the measured run-off calculated from the discharge curve and recorder charts, as follows :—

Months.	1925.		1926.		1927.	
	Rainfall.	Run-off.	Rainfall.	Run-off.	Rainfall.	Run-off.
January, February and March	0·8	3·9	4·0	4·6	0·6	1·7
April and May	14·8	2·2	7·7	1·8	6·7	0·6
June	14·6	23·1	5·4	2·4	25·0	32·2
July	23·6	31·5	34·5	43·4	38·9	52·1
August	21·5	21·0	27·8	44·0	10·6	17·7
September	9·8	9·0	11·8	11·0	7·2	6·9
October, November and December	14·4	12·7	8·4	8·1	7·1	7·4
Totals	99·5	103·4	99·6	115·3	96·1	118·5

This gives results of run-off in excess of rainfall especially in the south-west monsoon months. The rainfall of a catchment may be less than the run-off if the area of the catchment has been incorrectly surveyed or if subterranean waters, having their source outside the catchment come to the surface within the basin. Both these possibilities have been considered but dismissed as improbable. A close study of the rainfall and run-off records indicated that the deduced rainfall records were fairly accurate, but the accuracy of the run-off figures had to be questioned for the following reasons :—

The results of the gaugings showed that in many cases the ratio of surface to mean velocities varied from about 0·46 to 0·99 for observations taken at approximately the same stages. These variations were noticed especially in the gauging records of the south-west monsoon months, and might have been due to the strong south-west wind blowing down the river at this season, tending to increase the surface velocity. On the other hand at the lower stages of the river, during comparatively calm weather, the gaugings showed reasonably consistent results.

The rating curve was checked with the weir discharge curve calculated from the formula—

$$Q = 3{\cdot}4\ LH\sqrt{H}$$

(3·4 allows for the velocity of approach and leakage through the weir)

and these were found to agree closely for the lower stages up to a gauge height of 2·5 feet (plan $\frac{P\text{-}35}{F\text{-}2}$). Table V shows the run-off as measured at Pykara within the limit of reliability (2·5 feet gauge) for all the months of record. It will be seen therefrom that only in the summer and north-east monsoon months generally was the river in lower stages (below 2·5 feet reading on weir gauge) and that the discharges during the summer months do not vary considerably but are more or less independent of the rainfall. But from a perusal of the gauged results given in Table V it will be seen that the total discharge of the summer and north-east monsoon periods shown for the years gauged represent only about 20 per cent of the total discharge for the year, and that nearly 80 per cent of the run-off occurred in the south-west monsoon the results of which period only could not be relied on. So a different method of computing the run-off applicable to the whole year has been adopted and these results are only used to check its general correctness.

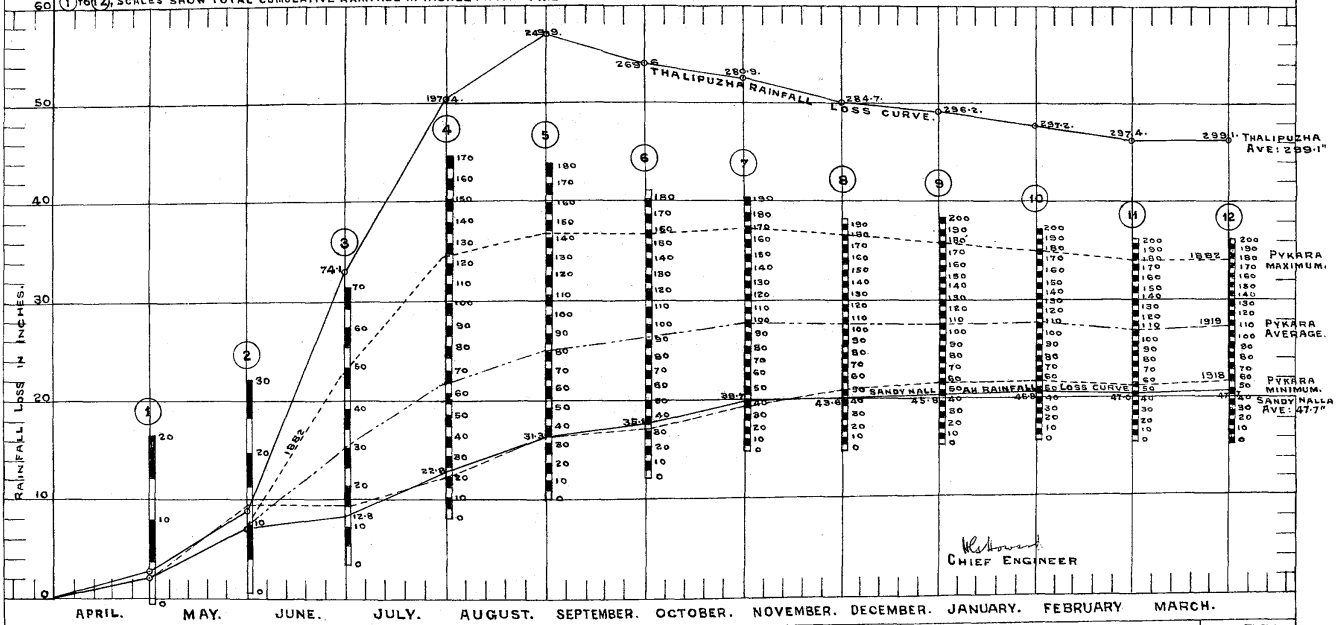
Method now used for calculating flow.—To deduce the monthly flow, rainfall and run-off statistics from other catchments in which the most similar conditions prevail have been taken, and the results applied to the computed rainfall on the Pykara catchment.

TABLE V.

Statement showing run-off from available records for months with gauge readings below 2·5 and rainfall for Pykara basin extracted from Table IV.

Year.	January.		February.		March.		April.		May.		June.		September.		October.		November.		December.	
	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual.	Basin rainfall in inches.	Run-off in inches actual.
1913	..	..	..	..	..	..	..	..	5·5	0·74	..	..	..	..	..	..	..	..	..	..
1914	..	..	..	..	..	..	..	..	6·6	0·38	..	..	..	..	..	..	..	..	..	..
1915	1·0	1·64	Nil	0·85	0·6	0·79	3·7	0·68	8·1	0·70	..	..	..	..	..	..	..	..	..	..
1916	..	..	Nil	1·12	Nil	0·81	1·6	0·62	10·8	0·70	..	..	..	..	..	..	..	..	..	..
1917	0·1	1·39	1·4	1·09	0·4	1·06	1·3	0·70	5·0	0·67	..	..	..	..	..	..	..	..	..	..
1918	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1919	..	..	..	..	..	..	5·1	0·80	..	..	..	..	..	..	..	..	..	..	..	..
1920	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1921	0·6	1·09	Nil	0·76	Nil	0·78	6·1	1·05	5·3	0·79	..	..	..	..	..	..	..	..	..	..
1922	0·1	0·57	Nil	0·76	0·1	0·73	1·0	0·54	..	..	..	..	..	..	..	..	..	..	..	..
1923	..	..	Nil	1·09	2·8	1·07	5·9	1·04	5 2	0·98	..	..	..	..	..	..	..	..	..	..
1924	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
1925	0·6	2·30	Nil	0·89	0·2	0·68	5·3	0·70	9·5	1·47	..	..	9·8	8·79	5·7	4·61	4·9	4·46	3·8	3·56
1926	2·5	2·32	Nil	1·24	1·5	1·03	2·2	0·87	5·5	0·90	5·4	2·41	..	..	4·1	4·23	3·4	2·51	0·9	1·37
1927	0·2	0·83	0·1	0·51	0·3	0·34	2·9	0·22	3·8	0·37	..	..	7·2	6·94	2·9	3·96	4·0	2·26	0·2	1·14
Total ..	5·1	10·14	1 5	8·31	5·9	7·24	35·1	7·22	65·3	7·70	..	..	..	..	12·7	12·80	12·3	9·23	4·9	6·07
Average ..	0·7	1·45	0·2	0·92	9·7	0·80	3·5	0·72	6·5	0·77	..	..	..	..	4·2	4·27	4·1	3·08	1·6	2·02

NOTE:— CURVES SHOWING AVERAGE MONTHLY DIFFERENCE BETWEEN RAINFALL & RUNOFF FOR THALIPUZHA (1924-28.) & SANDY NALLA (1925-27.) & DIFFERENCE CURVES FOR PYKARA BASIN FOR MAX., AV., & MIN. YEARS COMPUTED THERE FROM. (1) TO (12), SCALES SHOW TOTAL CUMULATIVE RAINFALL IN INCHES FROM APRIL:



EXAMPLE:—

LET THE CUMULATIVE RAINFALLS TO END OF AUGUST = 130", JULY = 100".

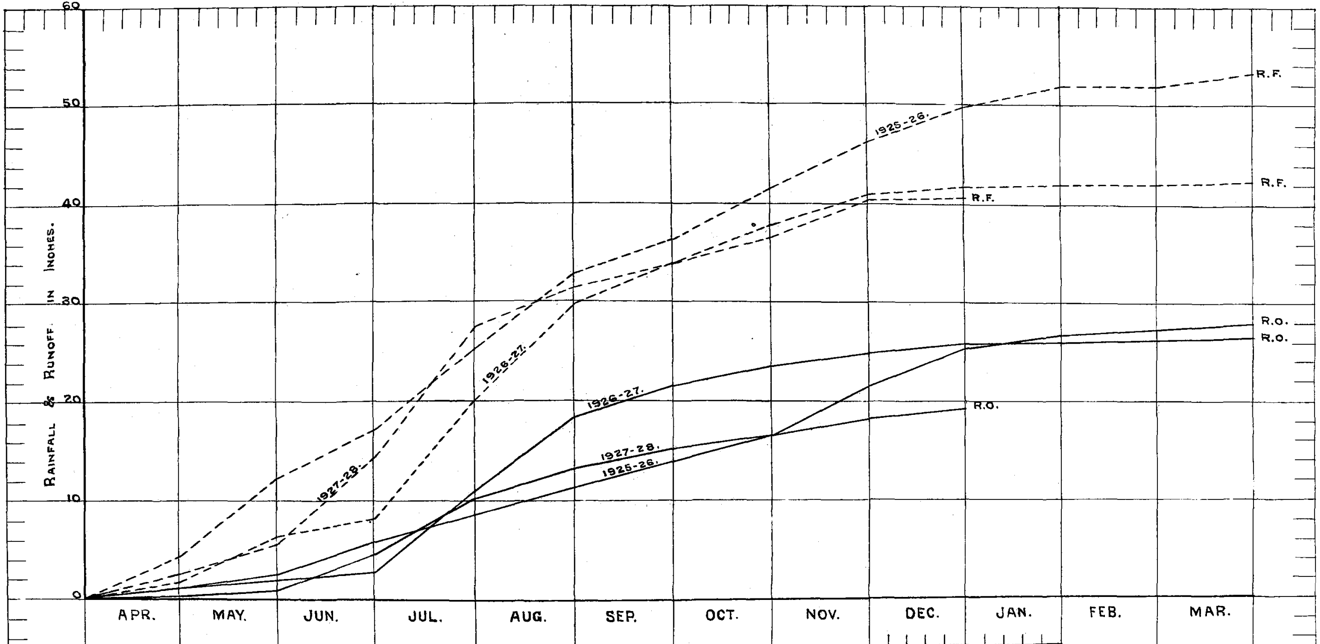
THEN - LOSSES TO END OF AUGUST = 34·4", JULY = 29·7" } AS READ FROM HOZ^L LINES DRAWN FROM VER^L SCALES 4 & 5 TO CUT RAINFALL LOSS SCALE AT LEFT HAND MARGIN.

SO CUMULATIVE RUNOFF TO END OF AUGUST = 130 - 34·4 = 95·6", JULY = 100 - 29·7 = 70·3".

SO RUNOFF IN AUGUST = 95·6 - 70·3 = 25·3" FOR A RAINFALL OF 30".

REFERENCES.	DRAWN BY, A. V. IYER.	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS.	No. P.33 / F.1
REVISIONS.	TRACED BY, P. PARAMASIVAN. CHECKED BY, R.N. IYER. APPROVED.	PYKARA RAINFALL LOSS CHART.	SCALE:- AS IN CHART. DATE:- 6-3-28.

5/18



H. G. Howard
CHIEF ENGINEER.

NOTE:-
R.F. = RAINFALL.
R.O. = RUNOFF.

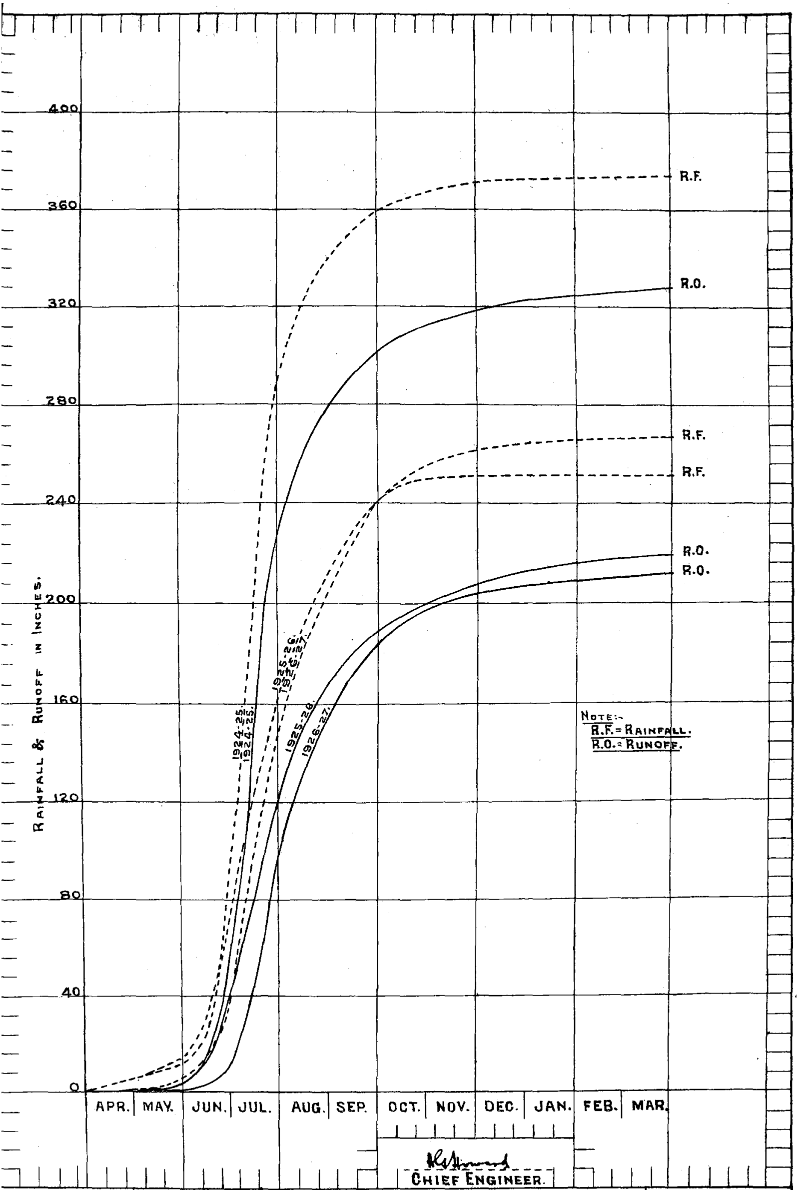
REFERENCES.

REVISIONS.

DRAWN BY, A.V.IYER.
TRACED BY, PARAMASIVAN.
CHECKED BY, P.N.IYER.
APPROVED BY

DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS.
PYKARA H. E. DEVELOPMENT.
RAINFALL & RUNOFF - SANDYNALLA.

NO. P. 32. F.1.
SCALE:- AS IN CHART.
DATE:- 2ND. MAY. 1928



CHIEF ENGINEER.

REFERENCES.	DRAWN BY, A.V. IYER.	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS.	No. P. 31. F. 1.
	TRACED BY, P. PARAMASIVAN.		
REVISIONS.	CHECKED BY, P.N. IYER.	PYKARA H. E. DEVELOPMENT.	SCALE:- AS IN CHART.
	APPROVED BY,	RAINFALL & RUNOFF — THALIPUZHA.	DATE:- 2-5-1928.

Thalipuzha.—This catchment is on the edge of the Western Ghats in the Wynaads and is subject to a very heavy rainfall, of which about 88 per cent occurs during the south-west monsoon. It is a small flat valley surrounded by high steep hills covered with thick grass and heavy jungle. The elevation varies between 2,800 and 6,000 feet, and the catchment area is 6·7 square miles. The statistics available are as follows :—

Years.	Average rainfall in inches.	Measured run-off in inches.	Run-off percentage.	Difference between rainfall and run-off in inches.
1924–25	375	328	88	47
1925–26	267	219	82	48
1926–27	255	212	83	43
1927–28	272	219	81	53

Sandy Nalla.—This catchment adjoins the Pykara and is similar to it as regards elevation and ground. The rainfall, however, is considerably lower and is affected only to a comparatively small extent by the south-west monsoon. The following are the statistics available :—

Years.	Average rainfall in inches.	Measured run-off in inches.	Run-off percentage.	Difference between rainfall and run-off in inches.
1925–26	53·2	27·8	52	26·5
1926–27	42·3	26·3	62	18·1
1927–28	42·1	21·3	51	20·8

The above statistics indicate that the relationship between rainfall and run-off is a rough difference for each catchment, and that the difference is greater for catchments with higher rainfalls.

Plan $\frac{\text{P-31}}{\text{F-1}}$ shows the variation between rainfall and run-off of the Thalipuzha, plotted cumulatively for the different months starting from April. Plan $\frac{\text{P-32}}{\text{F-1}}$ illustrates the same particulars for the Sandy Nalla.

The two *catchments have been taken as guides in deducing the run-off at* Pykara, as the Pykara basin rainfall is intermediate between those of the Thalipuzha and the Sandy Nalla, and as the difference between rainfall and run-off on the Pykara may therefore be expected to be some figure between those of the Sandy Nalla and the Thalipuzha. Table IV shows that the Pykara basin rainfall varies between a maximum of 180 inches with an 82 per cent south-west monsoon, and a minimum of 60 inches with only a 34 per cent south-west monsoon. These two extreme conditions approximate to those of the Thalipuzha and Sandy Nalla respectively, and it seems reasonable to assume that the total difference between rainfall and run-off in the wettest year will be considerab*ly greater than that of the driest, and that inter*mediate rainfalls will have proportionately intermediate differences. This assumption of a difference varying with the rainfall in the same catchment is justified by the variety of monsoon conditions which prevail in the catchment in different years.

Plan $\frac{\text{P-33}}{\text{F-1}}$ shows the average monthly differences between rainfall and run-off on the Thalipuzha and Sandy Nalla catchments respectively plotted cumulatively. Scales have been drawn showing the proportionate intermediate values of the losses for varying total rainfalls each month, and curves drawn for the maximum, average and minimum years *in the Pykara basin.*

The monthly run-offs in Table IV have been taken from the corresponding rainfalls on the scales constructed on Plan $\frac{\text{P-33}}{\text{F-1}}$.

The rainfall-run-off percentages from the figures on Table IV vary between a maximum of 81 and a minimum of 63. These do not appear unreasonable for this catchment.

To enable its probable accuracy and reasonableness to be gauged, Table VI has been prepared showing the measured discharges for all the months of record (see Table V) compared with the discharges as computed on Table IV. They conform reasonably closely.

Table VI shows that the run-off during the dry months of January, February and March is a more or less steady flow gradually diminishing from January to

March. This is in accordance with what one would expect, its magnitude depending on the previous monsoon condition and not on the rainfall in these dry months. The method adopted in computing the run-off during these months does not allow for exceptional conditions and therefore gives higher rates than are likely to have occurred during dry months when heavy rainfalls occurred. As there are only a few instances of these exceptional conditions during the 45 years period, and as these do not occur in the minimum years which have been taken for design purposes, they do not materially affect the accuracy of Table IV, and the method of computation has not therefore been modified for these individual months.

TABLE VI.

Statement showing the actual and computed run-offs in inches for periods for which the former is available.

—		January.	February.	March.	April.	May.	June.	July and August.	September.	October.	November.	December.	Total.
1915 ..	Actual	1·64	0·85	0·79	0·68	0·70	..	..	..	..	..	..	4·66
	Computed	1·2	0·7	0·3	1·2	1·70	..	..	..	..	..	..	5·10
1916 ..	Actual	..	1·12	0·81	0·62	0·70	..	..	..	..	..	.	3·25
	Computed	..	0·6	.	0·9	2·2	..	..	..	..	..	..	3·70
1917 ..	Actual	1·39	1·09	1·06	0·70	0·67	..	..	..	..	..	..	4·91
	Computed	0·3	1·7	0·1	0·9	0·6	..	..	..	..	..	..	3 0
1921 ..	Actual	1·09	0·76	0·73	1·05	0·79	..	..	..	..	..	..	4·42
	Computed	2·0	0·7	..	1·5	1·3	..	..	..	..	..	..	4·50
1922 ..	Actual	0·57	0·76	0·73	0·54	..	..	..	..	..	..	..	2 60
	Computed	0·6	0·7	Nil.	0·8	..	..	..	..	..	..	..	2·10
1923 ..	Actual	..	1·09	1 07	1·04	0·98	..	..	..	..	..	..	4·18
	Computed	..	0·6	2·2	1 5	1·3	..	..	..	..	..	..	5·6
1925 ..	Actual	2·30	0·89	0·68	0 70	1·47	..	..	8·79	4·61	4·46	3·56	27·40
	Computed	1·2	1·0	0·1	1·4	2·4	..	..	8·9	4·4	5·2	3·7	28·3
1926 ..	Actual	2·32	1·24	1·03	0·87	0·90	2·41	..	..	4·23	2·51	1·37	16·38
	Computed	2·5	0·5	1·1	1·0	0·8	2·9	..	..	3·0	3·9	1·2	16·9
1927 ..	Actual	0·83	0·51	0·34	0·22	0·37	..	..	6·94	3·96	2·26	1·14	16·51
	Computed	0·3	0·6	0·1	1·1	0·5	..	..	7·0	2·0	4·4	0·6	16·4

Note.—*Where heavy rainfalls occur in January, February and March, this method of computation gives excessive run-offs and should be modified.*

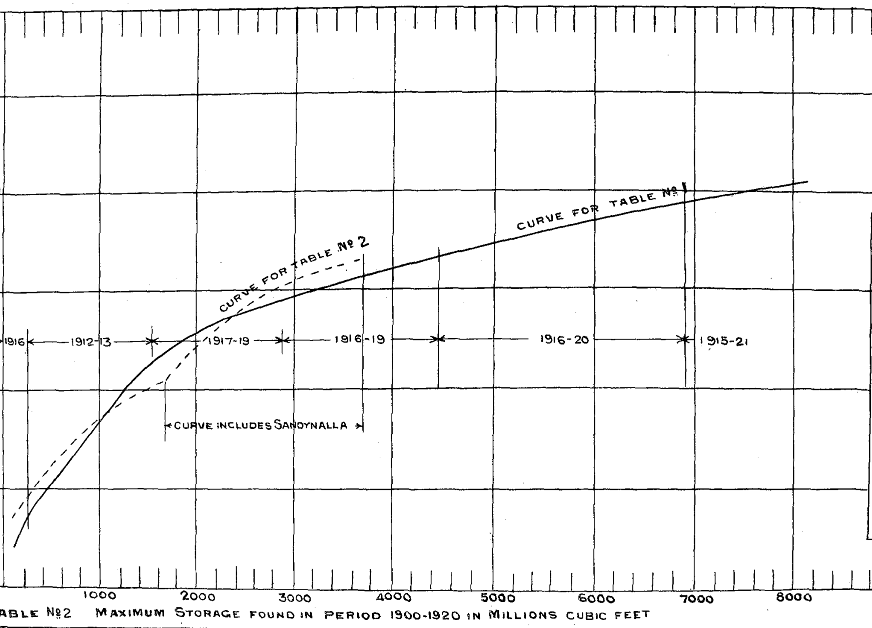
The monthly run-offs thus deduced and shown on Table IV may therefore be taken as reasonably correct.

These estimated monthly discharges in Table IV are the bases of all the following calculations.

The above is probably the most complete analysis yet attempted to arrive at the actual run-off of the Pykara catchment during the various seasons, and is believed to approximate actual conditions. More storage will be required for a given continuous flow than deduced in the Introductory Report. In fact, to ensure a continuous flow of 150 cusecs all the more economical storage sites must be developed except Parson's Valley.

If the figures are too conservative, the regulated run-off will be higher; if, on the other hand, the deduced figures are too high, more storages will have to be provided for. There is still the Parson's Valley site available for storages up to 360 million cubic feet effective, while the Pykara site can store 1,550 million cubic feet, of which only 900 million cubic feet is proposed to be stored now.

The first few years of operation depend only on a part of the run-off during the south-west monsoon being stored and utilized, and, as the readings taken during the dry season are undoubtedly reliable, the dispositions made for the initial stages of operation will not be changed. Meanwhile careful arrangements are being made to gauge the run-off of the various catchments during the next few years, so that long before it becomes necessary to consider seriously the utilization of the greater part of the run-off of a minimum year during the south-west monsoon, reliable flow data may be available.



GROSS
CUSECS
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

ABLE №2

NET DRAFT IN CUSECS	TOTAL STORAGE IN M.CFT.	INDIVIDUAL RESERVOIR CAPACITY IN MCFT.	
33.5	80	26	GLENMORGAN ONLY
92	1280	1200	
105	1680	400	
128	2130	450	
165	3680	1550	

H. G. Howard
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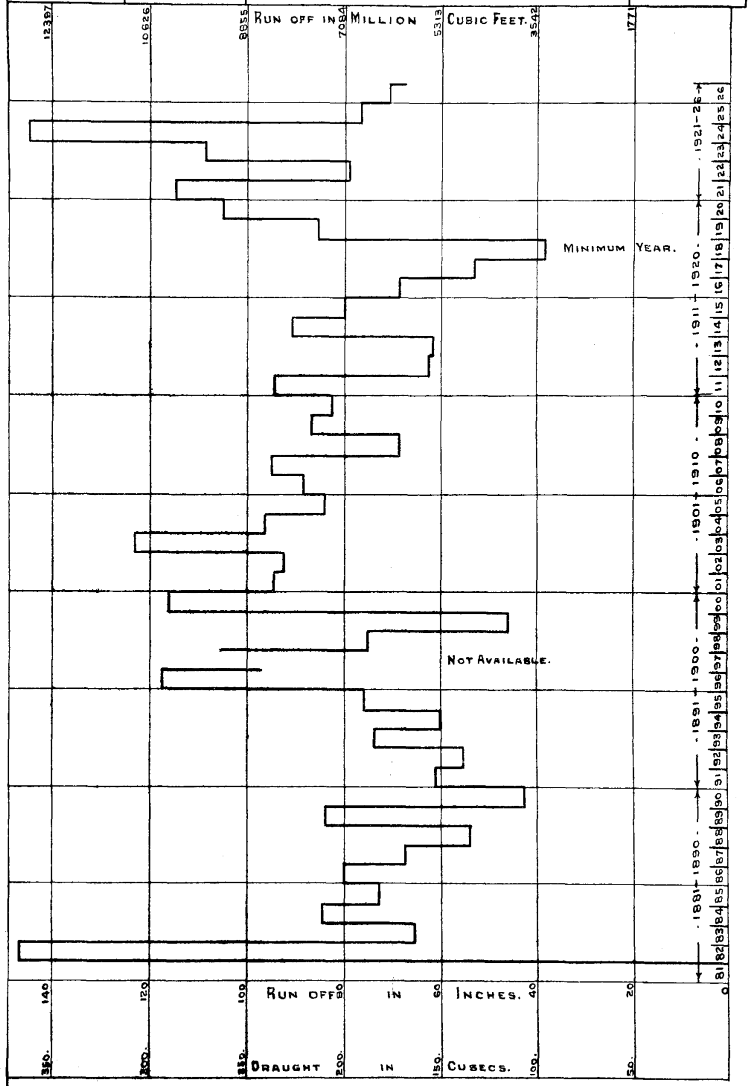
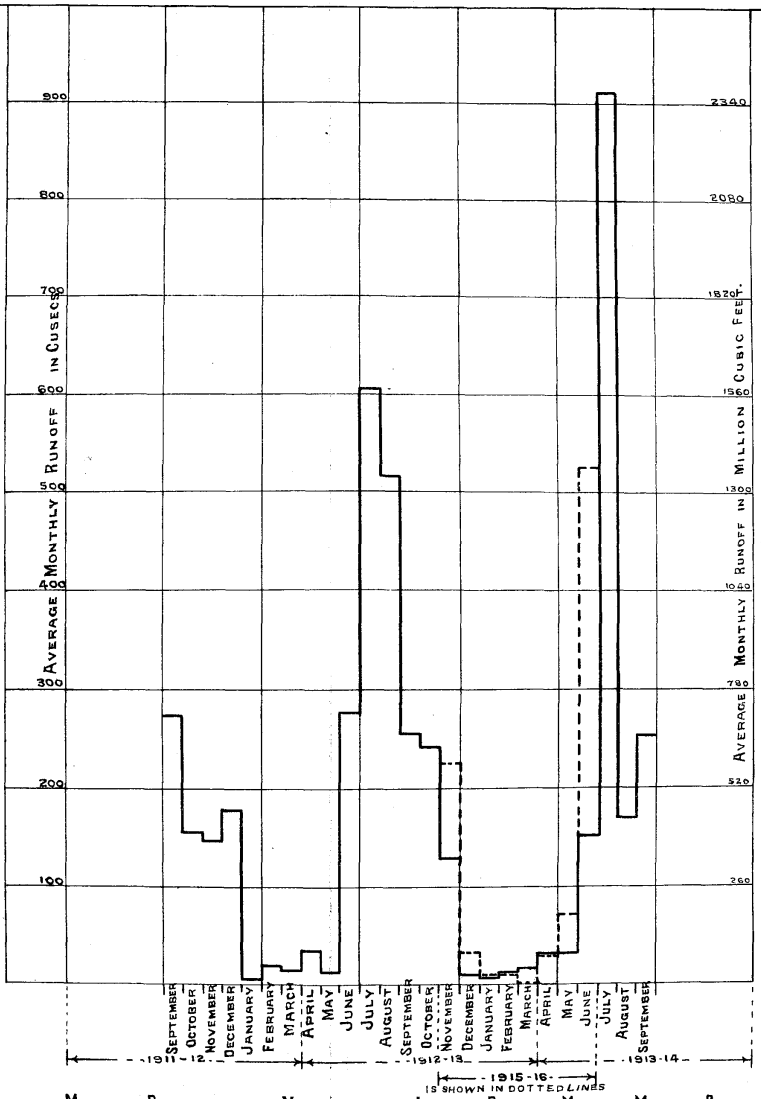
REFERENCES	DRAWN BY. A. V.	DEPARTMENT OF, HYDRO ELECTRIC DEVELOPMENT MA
	TRACED BY. M. DHANAKOTY	
REVISIONS FOR P.G / F.I DATED 11. 11. 27	CHECKED BY. P.N. IYER	PYKARA H.E. DEVELOPMEN
	APPOVED BY	DRAFT STORAGE CURV

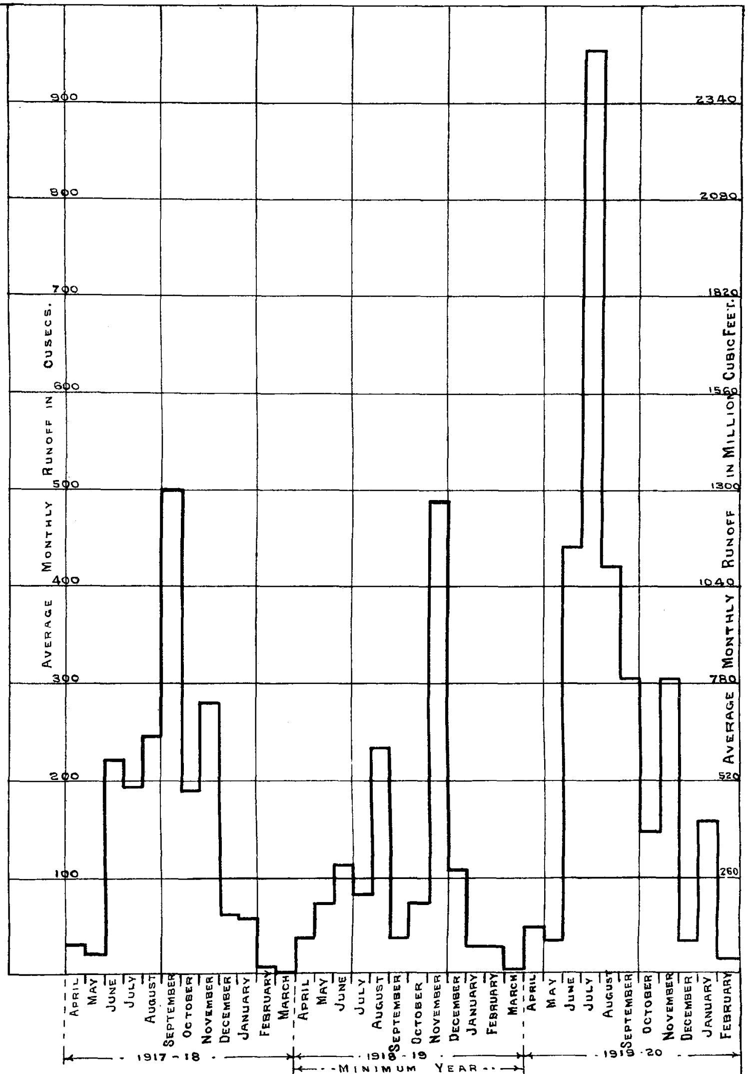
References.	Drawn By, A.V. Iyer.	Department. of Hydro-Electric Development. Madras.	No. P. 5.A. / F.3.
	Traced By, P. Paramasivan.	Pykara H. E. Development.	Scale... as in Chart.
Revisions. For P.5 / F.2 Dated 11-11-27	Checked By, P.N. Iyer.		
	Approved By,	Hydrographs – Pykara Basin.	Date:- 11-5-1928.



Annual Run off 44 Years. 1882-1926.



Monthly Run off for the Years with the Longest Period of Monthly Minimum Runoffs.

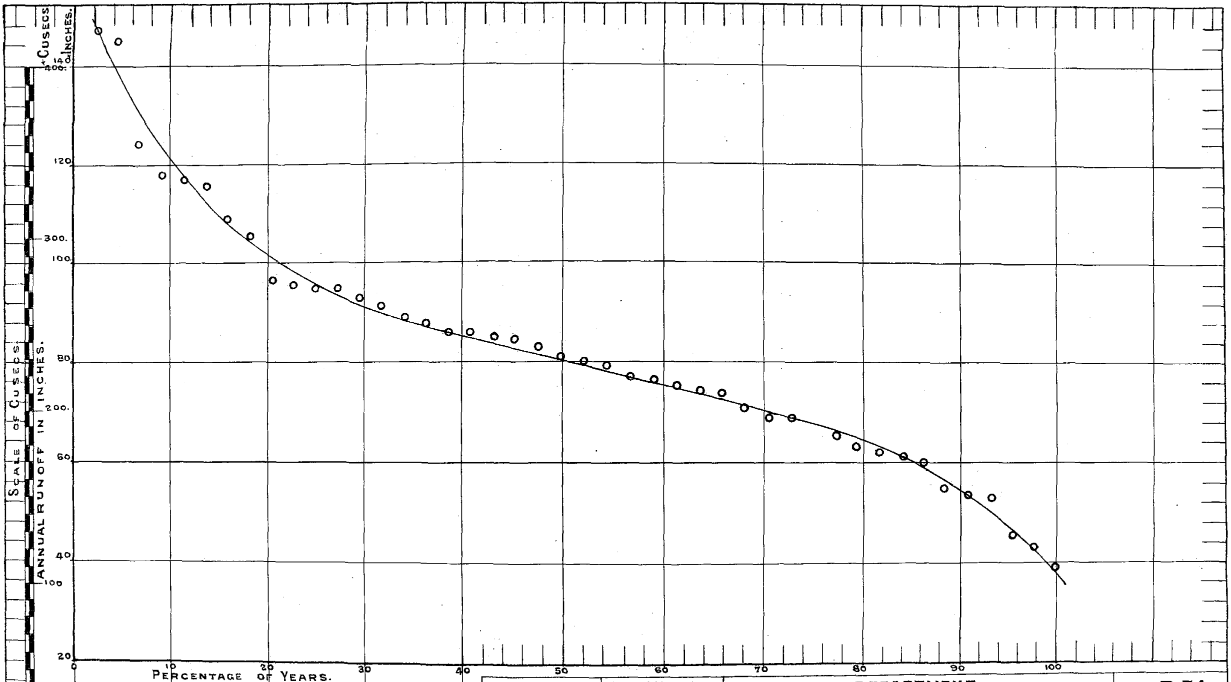


Monthly Runoff for the Year with Minimum Annual Runoff.

Chief Engineer.

Chief Engineer.

References.	Drawn By, A.V. Iyer.	Department. of Hydro-Electric Development. Madras.	No. P. 5.A. / F.3.
	Traced By, P. Paramasivan		
Revisions. For P.5 / F.2 Dated 11-11-27	Checked By, P.N. Iyer.	Pykara H.E. Development.	Scale:- as in Chart.
	Approved By,	Hydrographs – Pykara Basin.	Date:- 11-5-1928.



References.	Drawn by, A.V. Iyer.	Department. of Hydro-Electric Development. Madras.	No. P.34 / F.1
	Traced by, P. Paramasivan.		
Revisions.	Checked by, P. N. Iyer	Pykara H. E. Development.	Scale:- as in chart
	Approved by,	Duration Curve-45 Years Period.	Date=12-3-1929.

Chief Engineer

SECTION 3.—STORAGE.

To take full economical advantage of the Pykara Scheme, storages should be gradually developed to suit the varying load conditions. In many projects such methods are not possible, but fortunately this catchment is admirably suited for such a development. The ground is, in general, not suitable for very high dams owing to the high cost of the foundations. There is, however, bed rock at all possible dam-sites, and structures up to 100 feet can be constructed at a reasonable cost.

There are several reservoir sites in the catchment; in fact, it is one of the most flexible schemes involving storage, with which the writer is acquainted.

After a careful survey of all these sites, it was decided that the most economically feasible of those available were:—

	Run-off of catchment. Minimum year.	Run-off of catchment. 90 per cent year.	Approximate ratio of unit cost.
	M.C.FT.	M.C.FT.	
1. Makurti	1,080	1,614	15
2. Pykara modified	1,447	2,033	27
3. Porthimund	459	581	35
4. Sandy Nalla	627	848	43
5. Parson's Valley	396	517	50
6. Glen Morgan	66	84	81

It will be seen that Makurti is easily the most attractive site. Unit costs are, however, sometimes deceptive in that there is a tendency to construct for excessive capacities.

The question of the capacities of the various reservoirs is important. A site may be developed to store the minimum annual run-off of its catchment or an amount greater or less than this figure. When there are several reservoir sites and all are needed, careful study is necessary before a decision can be reached as to the best method of development.

An isolated power installation can obviously be developed only up to the run-off of the minimum year, if no shortage or carry-over is contemplated. In such cases the load in the earlier stages of development may not warrant the utilization of the whole of this run-off, so that only sufficient storage is required to tide over the worst season of the year. But minimum seasonal water conditions may not occur in the minimum year; it may happen in a year with a higher run-off. Hence care must always be taken that sufficient storage has been provided.

If there is any possibility of a single power development forming part of a system of power plants situated in other catchment areas, it clearly should be developed beyond minimum water conditions, that is, for an occasional shortage of water. The limits of such a development have to be decided more or less arbitrarily and based on judgment and experience. A ninety per cent year, for instance, allows an average shortage once in ten years, by ignoring all records from 90 per cent to 100 per cent. In the case of several power plants operating from different catchments, forming a power system, the diversity between the various run-offs may often cover, within certain limits, any individual deficiencies. Again, a stand-by steam plant will enable many schemes to be developed for a seventy per cent or even higher run-off. These observations are made to show that in deciding on the capacities of the various storage sites, due consideration must be given not only to the estimated load demands, but to the position of Pykara in a possibly larger and more extensive power system of the future.

A duration curve of the Pykara run-off for a 45-year period is shown in plan $\frac{\text{P.34}}{\text{F.1}}$. From this curve the average annual run-off, which can be expected for certain percentages of this period, is obtained.

According to table IV, the minimum year was 1918 with a total run-off of 3,382 million cubic feet. A hydrograph of this year is reproduced on plan $\frac{\text{P.5.A}}{\text{F.3}}$.

A mass curve (not reproduced) was drawn for the Pykara basin during the period 1901–1921 and the storages required, as deduced from this curve, for various run-offs are tabulated and also shown in the form of a curve—vide table I and curve I in plan $\frac{\text{P.6A.}}{\text{F.1}}$.

This curve indicates clearly the dividing line between seasonal and annual storages which corresponds to a flow around 115 cusecs. However the added increase in storage for a given flow is still reasonable up to about 150 cusecs, which quantity has been tentatively fixed as the economical limit.

If, however, all years down to the 90 per cent year are eliminated, results are obtained for ninety per cent conditions. The storages required under such conditions are obviously less for given draw-offs, and are shown in table VII.

TABLE VII.

Statement showing storages required to give varying rates of draft from the Pykara Basin in the 90 per cent minimum year.

Continuous draw-off in cusecs.	Equivalent in m.c.ft. per month.	90 per cent minimum year. January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total storage required.
Available quantities in m.c.ft.		53	53	80	106	142	780	1,000	840	770	292	434	195	..
20	52	..	..	..	..	..	..	..	..	..	..	..	..	..
30	78	25	25	..	..	..	..	..	..	..	..	..	..	50
40	104	51	51	24	..	..	..	..	..	..	..	..	..	126
50	130	77	77	50	24	..	..	..	..	..	..	..	..	228
60	156	102	102	76	49	13	..	..	..	..	..	..	..	341
70	181	128	128	101	75	39	..	..	..	..	..	..	..	471
80	*207*	*154*	*154*	*127*	*101*	*65*	..	..	..	..	..	..	12	613
90	233	180	180	153	127	91	..	..	..	..	..	..	38	759
100	259	206	206	179	153	117	..	..	..	..	..	..	64	925
110	285	232	232	205	179	143	..	..	..	..	..	..	90	1,081
120	311	258	258	231	205	169	..	..	..	..	..	..	116	1,297
130	337	284	284	257	231	195	..	..	..	..	..	..	142	1,439
140	363	310	310	283	257	221	..	..	..	..	..	..	168	1,549
150	*389*	*336*	*336*	*309*	*283*	*247*	..	..	..	..	..	..	*194*	*1,705*

Note.—January, February and March coming at the end of the year are taken before April so as to give the total deficit in one draught season in the 90 per cent year.

It should be noted that these curves and table only represent the Pykara basin taken as a whole, and do not include Sandy Nalla and Glen Morgan, nor the effect of developing several reservoirs. They were reproduced to show more clearly the comparative storages needed for various draw-offs under different conditions.

It has been decided that, where operating conditions permit, the most economical policy to follow in this case will be to develop the cheaper storage sites for run-offs greater than that of a minimum year, and the more costly sites for the minimum run-off or less. As long, however, as Pykara is the only generating plant on the system, operation will be strictly on a basis of minimum run-off for each catchment. In other words, reservoirs designed for minimum year conditions will store and distribute the whole run-off of the particular catchment in that year without spilling. Those designed for less will spill every year.

Similarly those designed for a ninety per cent year will store and distribute the run-off for that year without spilling, but will not fill when the run-offs are less than that of the ninety per cent year.

Bearing the preceding remarks in mind, and paying due attention to the load forecast, it is proposed to develop storages as shown below.

These storages will ensure the necessary continuous river flow, satisfy practical operating conditions, and involve the least annual charges.

Reservoir.	Effective individual reservoir capacity million cubic feet.	Effective total storage million cubic feet.	Flow cusecs.	Equivalent K.W.
1. Glen Morgan and forebay	80	80	33·5	6,700
2. Makurti	1,200	1,280	92	18,400
3. Porthimund	400	1,680	105	21,000
4. Sandy Nalla	450	2,130	128	25,600
5. Moyar	..	..	128	38,200
6. Pykara	1,550	3,680	165	44,300

The reservoir developments are shown in Table 2 and curve 2 of plan No. $\frac{P.6.A}{F.1}$. It should be noted that the two curves differ somewhat in that curve No. 2 includes the run-off of the Glen Morgan and Sandy Nalla catchments and requires less storage for the lower draw-offs. For the higher draw-offs there is little difference between the two curves.

This order of development does not follow that given in the table on page 13 for the following reasons.

The development of Glen Morgan and the forebay initially has to be decided solely on practical operating conditions.

A limited storage is necessary before the regular operating period commences, to provide water-supply for construction purposes. A small amount of storage is also needed to ensure a continuous flow to the auxiliary plant during the dry months. Low initial investment rather than low unit cost governs the decision in this case. Glen Morgan was the site chosen because it will also be needed later, as an alternative water-supply for cooling the transformers and bearings at the Power House and supplying the camp with water. It is also to be used as a regulating basin when the Sandy Nalla reservoir is constructed. No other site could fulfil these conditions so well. Owing to the high unit cost of this site, the capacity proposed is much below the minimum run-off of the catchment, and that given in the Introductory Report. It has now been fixed at 26 million cubic feet effective requiring a dam 45 feet high. When Sandy Nalla is developed it might be found advisable to increase the height. Similarly a regulating forebay is necessary, and its effective capacity as now decided upon is 53·5 million cubic feet. This is less than in previous estimates and involves the construction of two bunds; the upper one will be 39 feet high and the lower 62 feet. Besides economical considerations, the questions of seepage and design were important factors in deciding to decrease the capacity. As is proposed now, the forebay will provide water for approximately 2,675,000 K.W.H. This should be ample to take care of any emergency, until the Sandy Nalla reservoir and aqueduct are constructed. No accident to the main Pykara flume is anticipated, but should the unforeseen happen, the above emergency capacity should provide plenty of time for repairs.

Makurti and Porthimund were chosen next in the order named as it was found that this combination gave the lowest annual charges over a period of years, in spite of the fact that there will be a certain amount of idle capacity at Makurti for some time. The construction of these will ensure a regulated flow of 105 cusecs.

Sandy Nalla is placed fourth, more for reasons of expediency than economy. It is considered that at this stage of the development, an alternative feed to the forebay is justified.

Moyar will probably be constructed next, as the Madras load should have been connected by this time. This installation may be considered as a cheap storage site since, by generating power from the tail water of the Pykara plant, only a smaller draw-off from the existing reservoirs will be needed for a given amount of power.

The development of the Pykara site will depend on the final figures for annual run-off. It is a very good reservoir site, and the cost of the dam is fairly reasonable up to heights around 100 feet. To ensure a flow of 150 cusecs it is only necessary to store 900 million cubic feet. Storages, however, up to 1,550 million cubic feet are possible at this site.

Parson's Valley reservoir has been relegated to the last place on account of its high unit cost. Recent surveys indicate that a much higher structure will be needed to store the minimum run-off than was contemplated in the Introductory Report.

Working tables Nos. VIII to XII show in some detail the method of arriving at the storages required for the various run-offs, and are used for design purposes only.

Evaporation and absorption losses have been included in all the storage calculations, and have been determined from Table XIII which gives the available records of both measured and estimated losses in Indian reservoirs for the different

months. None of the reservoirs on which observations have been taken are situated at as high an elevation as Pykara, nor are they subjected to similar climatic conditions. The estimated losses for the Panam lake appear to conform most reasonably to the Pykara seasonal weather conditions except that the former is at a considerably lower elevation and has consequently a higher average temperature than the latter. The monthly losses at Pykara are therefore taken as being roughly proportionate to those at Panam but reduced to allow for the colder climate.

The average monthly temperature at Pykara is 58° F. varying between 62° F. in April and May, and 53° F. in December and January.

Parker gives a total annual loss of 57 inches for a mean temperature of 60° F.

The monthly losses adopted for Pykara are shown at the foot of table XIII. These have been used in the above working tables.

Although provision has been made for all losses, a substantial reserve storage for contingencies will always be retained during the operation period.

Flood discharges.—These have been calculated as follows:—

Basin.	Catchment area in square *miles*.	Iso-hyetal ratio from Table III.	Flood discharge co-efficient 'C' arrived at = Pykara co-efficient 1,800 × Iso hyetal ratio ÷ 1·4.	Maximum discharge as calculated from 'C' in column 4 and formula $Q = CM^{2/3}$.
Pykara	38·12	1·4	* 1,800	20,000 cusecs.
Glen Morgan	1·00	1·0	1,300	1,300 ,,
Forebay	0·33	1·0	1,300	621 ,,
Parson's Valley	5·60	1·1	1,400	4,400 ,,
Makurti	9·65	1·8	2,300	10,000 ,,
Porthimund	3·22	1·9	2,400	5,000 ,,
Sandy Nalla	17·3	0·70	900	6,020 ,,

* The maximum discharge during the high floods of 1924 was reported by the Chief Engineer for Irrigation to be *20,120. The calculated co-efficient from this discharge for the Pykara combined catchment comes to 1,800.*

TABLE VIII.

Working table for the Glen Morgan Reservoir.

(Pykara 90 per cent minimum and Glen Morgan minimum year.)

—	Million cubic feet.											
	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1. Pykara flow in 90 per cent minimum year.	53·0	53·0	80·0	106·0	142·0	780·0	1,000·0	840·0	770·0	292·0	434·0	195·0
2. Forebay opening balance and supply from the Pykara river during the month.	106·5	71·5	80·0	106·0	160·1	833·5	1,053·5	893·5	823·5	345·5	487·5	248·5
3. Replenishment from Glen Morgan Reservoir.	Nil.	16·4	7·1	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
4. Evaporation	0·9	0·8	Nil.	0·8	1·3	0·6	0·6	0·6	0·6	1·0	1·0	1·0
5. Draw-off for power 33·5 cusecs.	87·1	87·1	87·1	87·1	87·1	87·1	87·1	87·1	87·1	87·1	87·1	87·1
6. Forebay closing balance ..	18·5	Nil.	Nil.	18·1	← Reservoir full.			Excess allowed to surplus. →				
Glen Morgan Reservoir—												
1. Glen Morgan flow in minimum year.	Nil.	1·6	Nil.	3·3	3·0	11·4	12·3	8·2	6·8	11·6	6·1	1·6
2. Draw-off for water-supply	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3	0·3
3. Evaporation	0·8	0·8	0·4	0·3	0·4	0·3	0·4	0·5	0·5	0·8	0·8	0·8
4. Draw-off for power into Forebay.	Nil.	15·4	7·1	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
5. Accumulation or deficiency during the month.	—1·1	—15·9	— 7·8	2·7	2·3	10·8	11·6	7·4	6·0	10·5	5·0	0·5
6. Storage at the end of the month.	24·9	9·0	1·2	2·7	5·0	15·8	← Reservoir full. Excess allowed to surplus. →					

Effective capacity at F.R.L. $\frac{\text{in Forebay 53·5 million cubic feet}}{\text{in Glen Morgan 26·0 million cubic feet}}$.

Table IX.

Working table for Makurti reservoir for period November 1916—August 1919.

(Subsequent to Glen Morgan only.)

—	Million cubic feet.																
	1916.		1917.												1918.		
	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.
Pykara flow excluding Makurti basin	259·9	76·9	18·0	112·9	Nil.	59·8	41·8	363·0	312·2	401·6	833·4	332·2	510·8	106·2	103·9	9·0	Nil.
Forebay opening balance and supply from the Pykara river and Glen Morgan reservoir during the month.	313·4	130·4	18·0	129·3	7·1	59·8	41·8	363·0	365·7	455·1	886·9	385·7	564·3	159·7	103·9	25·4	7·1
Replenishment from the Makurti reservoir ..	Nil.	109·7	221·2	109·9	232·1	179·4	197·4	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	80·4	135·3	213·8	232·1
Evaporation	1·0	0·9	Nil.	Nil.	Nil.	Nil.	Nil.	0·6	0·6	0·6	0·6	1·0	1·0	0·9	Nil.	Nil.	Nil.
Draw-off for power (92 cusecs)	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2
Forebay closing balance	53·5	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	53·5	53·5	53·5	53·5	53·5	53·5	Nil.	Nil.	Nil.	Nil.
Surplus running to waste	19·7	..	..	..	..	..	..	69·7	72·4	161·8	593·6	92·0	270·6	..	..	..	..
Makurti reservoir.																	
Makurti flow	112·1	38·1	9·0	38·1	9·0	20·2	11·2	213·0	201·8	244·4	459·6	145·8	215·2	44·8	38·1	9·0	Nil.
Evaporation	13·8	13·5	12·7	16·7	15·4	13·1	10·4	4·5	5·7	6·8	7·9	13·8	13·8	13·7	13·3	17·5	15·6
Draw-off for power into forebay	Nil.	109·7	221·2	109·9	232·1	179·4	197·4	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	80·4	135·3	213·8	232·1
Accumulation or deficiency during the month ..	98·3	— 85·1	—224·9	— 88·5	—238·5	—172·3	—196·6	208·5	196·1	237·6	451·7	132·0	201·4	—49·3	—110·5	—222·3	— 247·7
Storage at the end of the month	1,200	1,114·9	890·0	801·5	563·0	390·7	194·1	402·6	598·7	836·3	1,200	1,200	1,200	1,150·7	1,040·2	817·9	570·2
Surplus	98·3	..	..	..	..	..	..	..	..	..	88·0	132·0	201·4	..	..	..	..

Effective reservoir capacity to F.R.L.= 1,200 million cubic feet.

Table IX—*cont.*

Working table for Makurti reservoir for period November 1916—August 1919—*cont.*

(Subsequent to Glen Morgan only.)

	Million cubic feet.																
	1918—*cont.*									1919.							
	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
Pykara flow excluding Makurti basin	72·3	138·9	202·3	120·1	380·1	48·6	130·0	896·1	202·3	50·8	53·1	6·8	92·6	66·6	749·6	1,640·7	714·7
Forebay opening balance and supply from the Pykara river and Glen Morgan reservoir during the month.	72·3	138·9	202·3	120·1	380·1	102·1	130·0	896·1	255·8	66·6	69·5	13·9	92·6	66·6	749·6	1,694·2	768·2
Replenishment from the Makurti reservoir ..	166·9	100·3	36·9	119·1	Nil.	137·7	109·2	Nil.	Nil.	173·2	169·7	225·3	146·6	172·6	Nil.	Nil.	Nil.
Evaporation	Nil.	Nil.	Nil.	Nil.	0·6	0·6	Nil.	1·0	0·8	0·6	Nil.	Nil.	Nil.	Nil.	0·6	0·6	0·6
Draw-off for power (92 cusecs)	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2	239·2
Forebay closing balance	Nil.	Nil.	Nil.	Nil.	53·5	Nil.	Nil.	53·5	15·8	Nil.	Nil.	Nil.	Nil.	Nil.	53·5	53·5	53·5
Surplus running to waste	..	..	..	..	86·8	..	..	602·4	..	..	..	..	..	..	456·3	1,400·9	474·9
Makurti reservoir.																	
Makurti flow	24·7	47·1	89·7	91·9	230·9	40·4	65·0	369·9	80·7	20·2	17·9	2·2	31·4	23·4	392·4	901·3	410·3
Evaporation	13·1	11·8	4·9	4·7	5·6	6·0	9·1	10·5	11·9	11·6	14·9	12·3	9·5	5·5	3·8	7·3	13·8
Draw-off for power into forebay	166·9	100·3	36·9	119·1	Nil.	137·7	109·2	Nil.	Nil.	173·2	169·7	225·3	146·6	172·6	Nil.	Nil.	Nil.
Accumulation or deficiency during the month ..	−155·3	−65·0	47·9	−31·9	225·3	−103·3	−53·3	359·4	68·8	−164·6	−166·7	−235·4	−124·7	−155·7	388·6	894·0	396·5
Storage at the *end* of the month	414·9	349·9	397·8	365·9	591·2	487·9	434·6	794·0	862·8	698·2	531·5	296·1	171·4	15·7	404·3	1,200·0	1,200·0
Surplus	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	98·3	396·5

Effective reservoir capacity to F.R.L.= 1,200 million cubic feet.

TABLE X.

Working table for the Porthimund reservoir for period November 1916—August 1919.

(Subsequent to Glen Morgan and Makurti.)

—	Million cubic feet.																		
	1916.		1917.												1918.				
	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.
Pykara flow excluding Makurti and Porthimund basins.	211·3	60·4	14·3	94·9	Nil.	53·1	33·6	293·4	246·4	326·1	689·0	258·9	410·6	85·3	87·4	6·0	Nil.	62·6	114·2
Forebay opening balance	53·5	53·5	..	..	..	..	..	..	19·8	..	52·5	53·5	53·5	53·5	..	..	..	..	..
Supply from the Pykara river ..	211·3	60·4	14·3	94·9	..	53·1	33·6	293·4	246·4	326·1	689·0	258·9	410·6	85·3	87·4	6·0	..	62·6	114·2
Supply from the Glen Morgan reservoir.	..	..	..	16·4	7·1	..	..	..	..	..	..	..	..	..	..	16·4	7·1	..	..
Supply (and surplus) from Makurti reservoir during the month.	98·3	109·7	221·2	109·9	232·1	179·4	197·4	..	..	..	(88·0)	(132·0)	(201·4)	80·4	135·3	213·8	232·1	166·9	100·3
Total ..	363·1	223·6	235·5	221·2	239·2	232·5	231·0	293·4	266·2	326·1	829·5	444·4	665·5	219·2	222·7	236·2	239·2	229·5	214·5
Replenishment from the Porthimund reservoir.	Nil.	50·2	37·5	51·8	33·8	40·5	42·0	Nil.	7·4	Nil.	Nil.	Nil.	Nil.	54·6	50·3	36·8	33·8	43·5	58·5
Evaporation	1·0	0·8	Nil.	Nil.	Nil.	Nil.	Nil.	0·6	0·6	0·6	0·6	1·0	1·0	0·8	Nil.	Nil.	Nil.	Nil.	Nil.
Draw-off for power (105 cusecs) ..	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0
Forebay closing balance	53·5	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	19·8	Nil	52·5	53·5	53·5	53·5	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.
Surplus running to waste	35·6	..	..	..	..	..	..	..	..	..	502·4	116·9	338·0	..	..	..	..	..	..
Porthimund reservoir—																			
Porthimund basin flow	48·6	16·5	3·7	18·0	1·5	6·7	8·2	69·6	65·8	75·5	144·4	73·3	100·2	20·9	16·5	3·0	Nil.	9·7	24·7
Evaporation	5·1	5·1	4·8	6·0	5·8	5·2	4·8	2·1	2·5	2·7	3·0	5·1	5·1	5·0	4·7	6·2	5·8	5·3	4·8
Draw-off for power into forebay ..	Nil.	50·2	37·5	51·8	33·8	40·5	42·0	Nil.	7·4	Nil.	Nil.	Nil.	Nil.	54·6	50·3	36·8	33·8	43·5	58·5
Accumulation or deficiency during the month.	43·5	— 38·8	— 38·6	— 39·8	— 37·9	— 39·0	— 38·6	67·5	55·9	72·8	141·4	68·2	95·1	— 38·7	— 38·5	— 40·0	— 39·6	-39·1	— 38·6
Storage at the end of the month ..	400·0	361·2	322·6	282·8	244·9	205·9	167·3	234·8	290·7	363·5	400·0	400·0	400·0	361·3	322·8	282·8	243·2	204·1	165·5
Surplus	43·5	..	..	..	..	..	..	..	..	..	104·9	68·2	95·1	..	..	..	..	..	..

Effective reservoir capacity to F.R.L. = 400 million cubic feet.

TABLE X—*cont.*

Working table for Porthimund reservoir for period November 1916—August 1919—*cont.*

(Subsequent to Glen Morgan and Makurti.)

	Million cubic feet.														
	1918—*cont.*							1919.							
	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
Pykara flow excluding Makurti and Porthimund basins.	165·6	85·7	309·0	35·1	94·1	720·3	164·2	38·8	46·4	6·1	81·4	53·1	619·4	1,355·0	585·0
Forebay opening balance—	..	..	..	35·5	..	..	53·5	..	..	..	..	..	..	53·5	53·5
Supply from the Pykara river ..	165·6	85·7	309·0	35·1	94·1	720·3	164·2	38·8	46·4	6·1	81·4	53·1	619·4	1,355·0	585·0
Supply from the Glen Morgan reservoir.	..	..	..	..	..	..	..	..	16·4	7·1	..	..	..	..	..
Supply (and surplus) from Makurti reservoir during the month.	36·9	119·1	..	137·7	109·2	..	..	173·2	169·7	225·3	146·6	172·6	..	*98·3*	*396·5*
Total ..	202·5	204·8	309·0	208·3	203·3	720·3	217·7	212·0	232·5	238·5	228·0	225·7	619·4	1,506·8	1,035·0
Replenishment from the Porthimund reservoir.	70·5	68·2	Nil.	65·2	69·7	Nil.	56·1	61·0	40·5	34·5	45·0	47·3	Nil.	Nil.	Nil.
Evaporation	Nil.	Nil.	0·5	0·5	Nil.	1·0	0·8	Nil.	Nil.	Nil.	Nil.	Nil.	0·6	0·6	0·6
Draw-off for power (105 cusecs) ..	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0	273·0
Forebay closing balance	Nil.	Nil.	35·5	Nil.	Nil.	53·5	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	53·5	53·5	53·5
Surplus running to waste	..	..	..	..	..	392·8	..	..	..	..	..	..	292·3	1,179·7	707·9
Porthimund reservoir—															
Porthimund basin flow	36·7	34·4	71·1	13·5	35·9	175·8	38·1	12·0	6·7	0·7	11·2	13·5	130·2	285·7	129·7
Evaporation	2·5	1·6	1·8	1·8	2·4	3·1	3·9	3·5	5·7	4·6	3·4	2·4	1·5	2·5	3·1
Draw-off for power into forebay ..	70·5	68·2	Nil.	65·2	69·7	Nil.	56·1	61·0	40·5	34·5	45·0	47·3	Nil.	Nil.	Nil.
Accumulation or deficiency during the month.	− 36·3	− 35·4	69·3	− 53·5	− 36·2	172·7	− 21·9	− 52·5	− 39·5	− 38·4	− 37·2	− 36·2	128·7	283·2	126·6
Storage at the end of the month ..	129·2	93·8	163·1	109·6	73·4	246·1	224·2	171·7	132·2	93·8	56·6	20·4	149·1	400·0	400·0
Surplus	..	..	..	..	..	..	..	..	..	..	..	..	..	*32·3*	*126·6*

Effective reservoir capacity to F.R.L. = 400 million cubic feet.

Table XI.

Working table for Sandy Nalla reservoir for period September 1916—August 1919.

(Subsequent to Glen Morgan, Makurti and Porthimund.)

	Million cubic feet.																		
	1916.				1917.												1918		
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.
Pykara flow excluding Porthimund and Makurti basins.	496·4	338·9	211·3	60·4	14·3	94·9	..	53·1	33·6	293·4	246·4	326·1	689·0	258·9	410·6	85·3	87·4	6·0	..
Forebay opening balance	53·5	53·5	53·5	53·5	..	..	..	..	..	..	..	..	..	53·5	53·5	53·5	..	..	..
Supply from the Pykara river.. ..	496·4	338·9	211·3	60·4	14·3	94·9	..	53·1	33·6	293·4	246·4	326·1	689·0	258·9	410·6	85·3	87·4	6·0	..
Supply from the Glen Morgan reservoir.	..	..	..	.	..	16·4	7·1	..	..	..	..	..	..	..	..	..	..	16·4	7·1
Supply (and surplus) from Makurti reservoir.	..	..	(98·3)	109·7	221·2	109·9	232·1	179·4	197·4	..	..	..	(88·0)	(132·0)	(201·4)	80·4	135·3	213·8	232·1
Supply (and surplus) from Porthimund reservoir during the month.	..	..	(43·5)	50·2	37·5	51·8	33·8	40·5	42·0	..	7·4	..	(104·9)	(68·2)	(95·1)	54·6	50·3	36·8	33·8
Total ..	..	..	406·6	273·8	273·0	273·0	273·0	273·0	273 0	293·4	253·8	326·1	881·9	512·6	760·6	273·8	273·0	273·0	273·0
Replenishment from the Sandy Nalla reservoir.	Nil.	Nil.	Nil.	59·8	59·8	59·8	59·8	59·8	59·8	39·4	72·0	6·7	Nil.	Nil.	Nil.	59·8	59·8	59·8	59·8
Evaporation	0·6	1·0	1·0	0·8	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	0·6	0·8	0·9	0·8	Nil.	Nil.	Nil.
Draw-off for power (128 cusecs) ..	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8
Forebay closing balance	53·5	53·5	53·5	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	53·5	53·5	53·5	Nil.	Nil.	Nil.	Nil.
Surplus running to waste	..	..	(19·3)	..	..	..	..	..	..	..	..	..	(496·0)	(125·5)	(378·4)	..	..	..	..
Sandy Nalla Reservoir—																			
Sandy Nalla flow	112·4	224·8	140·5	28·1	4·0	48·2	..	32·1	16·1	44·1	8·0	16·1	164·6	176·6	301·0	48·2	40·1	8·0	4·0
Evaporation	4·5	7·5	7·5	7·3	6·9	9·0	8·4	7.5	6·9	2·8	2·6	2·4	2·9	6·5	7·5	7·4	7·2	9·4	8·7
Draw-off for power into forebay ..	Nil.	Nil.	Nil.	59·8	59·8	59·8	59·8	59·8	59·8	39·4	79·0	6·7	Nil.	Nil.	Nil.	59·8	59·8	59·8	59·8
Accumulation or deficiency during the month.	107·9	217·3	133·0	— 39·0	— 62·7	— 20·6	— 68·2	—35·2	— 50·6	1·9	— 73·6	7·0	161·7	171·1	293·5	— 19·0	— 26·9	— 61·2	— 64·5
Storage at the end of the month ..	450·0	450·0	450·0	411·0	348·3	327·7	259·5	224·3	173·7	175·6	102·0	109·0	270·7	441·8	450·0	431·0	404·1	342·9	278·4
Surplus	*107·9*	*217·3*	*133·0*	..	..	..	..	..	..	..	..	..	..	..	285·3	..	..	..	..

Effective reservoir capacity to F.R.L. = 450 million cubic feet.

TABLE XI—*cont.*

Working table for Sandy Nalla reservoir for period September 1916—August 1919—*cont.*

(Subsequent to Glen Morgan, Makurti and Porthimund.)

—	Million cubic feet.																
	1918—*cont.*									1919.							
	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August
Pykara flow excluding Porthimund and Makurti basins.	62·6	114·2	165·6	85·7	309·0	35·1	94·1	720·3	164·2	38·8	46·4	6·1	81·4	53·1	619·4	1,355·0	585·0
Forebay opening balance	..	..	..	..	..	..	..	..	53·5	..	..	..	..	..	..	..	..
Supply from the Pykara river ..	62·6	114·2	165·6	85·7	309·0	35·1	94·1	720·3	164·2	38·8	46·4	6·1	81·4	53·1	619·4	1,355·0	585·0
Supply from the Glen Morgan reservoir.	..	..	..	..	..	..	..	..	..	..	16·4	7·1	..	..	..	..	..
Supply (and surplus) from Makurti reservoir.	166·9	100·3	36·9	119·1	..	137·7	109·2	..	..	173·2	169·7	225·3	146·6	172·6	..	(98·3)	(396·5)
Supply (and surplus) from Porthimund *reservoir* during the month.	43·5	58·5	70·5	68·2	..	65·2	69·7	..	56·1	61·0	40·5	34·5	45·0	47·3	..	(32·3)	(126·6)
Total .	273·0	273·0	273·0	273·0	309·0	238·0	273·0	720·3	273·8	273·0	273·0	273·0	273·0	273·0	619·4	1,485·6	1,108·1
Replenishment from the Sandy Nalla reservoir.	59·8	59·8	59·8	59·8	23·8	94·8	59·8	Nil.	59·8	59·8	59·8	59·8	59·8	59·8	Nil.	Nil.	Nil.
Evaporation	Nil	Nil.	Nil.	Nil.	Nil	Nil.	Nil.	1·0	0·8	Nil	Nil.	Nil.	Nil.	Nil.	0·6	0·6	0·6
Draw-off for power (128 cusecs) ..	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8
Forebay closing balance	Nil.	Nil.	Nil	Nil.	Nil.	Nil.	Nil.	53·5	Nil.	Nil.	Nil.	Nil.	Nil.	Nil.	53·5	53·5	53·5
Surplus running to waste	..	..	..	..	..	..	..	333·0	..	..	..	..	..	..	232·5	1,098·7	721·2
Sandy Nalla reservoir—																	
Sandy Nalla flow	40·1	68·2	8·0	24·1	8·0	8·0	40·1	537·8	108·4	24·1	24·1	12·0	52·2	24·1	168·6	389·3	32·1
Evaporation	7·8	7·6	3·1	2·8	2·6	2·3	3·0	6·8	7·5	7·3	9·6	8·9	8·4	7·9	4·3	4·5	4·5
Draw-off for power into forebay .	59·8	59·8	59·8	59·8	23·8	94·8	59·8	Nil.	59·8	59·8	59·8	59·8	59·8	59·8	Nil.	Nil.	Nil.
Accumulation or deficiency during the month.	— 27·5	0·8	— 54·9	— 38·5	— 18·4	— 89·1	— 22·7	531·0	41·1	— 43·0	— 45·3	— 56·7	— 16·0	— 43·6	164·3	384·8	27·6
Storage at the end of the month ..	250·9	251·7	196·8	158·3	139·9	50·8	28·1	450·0	450·0	407·0	361·7	305·0	289·0	245·4	409·7	450·0	450·0
Surplus	..	..	..	..	..	..	..	109·1	41·1	..	..	..	..	..	..	344·5	27·6

Effective reservoir capacity to F.R.L. = 450 million cubic feet.

TABLE XII.

Working table for Pykara No. 1 Reservoir for period September 1916—August 1919.

(Subsequent to Glen Morgan, Makurti, Porthimund and Sandy Nalla.)

—	Million cubic feet.																	
	1916.				1917.												1918.	
	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.
Pykara flow excluding Makurti and Porthimund basins.	496·4	338·9	211·3	60·4	14·3	94·9	..	53·1	33·6	293·4	246·4	326·1	689·0	258·9	410·6	85·3	87·4	6·0
Supply from the Pykara river ..	496·4	338·9	211·3	60·4	14·3	94·9	..	53·1	33·6	293·4	246·4	326·1	689·0	258·9	410·6	85·3	87·4	6·0
Supply from Glen Morgan reservoir.	..	..	..	..	..	16·4	7·1	..	..	..	..	..	..	..	..	..	..	16·4
Supply (and surplus) from Makurti reservoir.	.	*320·3*	*98·3*	109·7	221·2	109·9	232·1	179·4	197·4	..	..	..	*88·0*	*132·0*	*201·4*	80·4	135·5	213·8
Supply (and surplus) from Porthimund reservoir.	..	*85·4*	*43·5*	50·2	37·5	51·8	33·8	40·5	42·0	..	7·4	..	*104·9*	*68·2*	*95·1*	54·6	50·3	36·8
Supply (and surplus) from Sandy Nalla reservoir.	..	*217·3*	*133·0*	59·8	59·8	59·8	59·8	59·8	59·8	39·4	79·0	6·7	..	..	*285·3*	59·8	59·8	59·8
Total supply available for storage or draft during the month.	..	961·9	486·1	280·1	332·8	332·8	332·8	332·8	332·8	332·8	332·8	332·8	881·9	459·1	992·4	280·1	332·8	332·8
Replenishment from the Pykara reservoir.	Nil.	Nil.	Nil.	167·3	113·8	119·5	118·3	117·1	115·7	104·0	103·6	102·7	Nil.	Nil.	Nil.	167·2	113·5	119·5
Evaporation	..	18·9	18·9	18·4	17·6	23·3	22·1	20·9	19·5	7·8	7·4	6·5	7·7	14·6	17·0	18·3	17·3	23·3
Draw-off for power (165 cusecs) ..	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0
Accumulated storage or deficit ..	..	514·0	38·2	—167·3	—113·8	—119·5	—118·3	—117·1	—115·7	—104·0	—103·6	—102·7	446·2	15·5	546·4	—167·2	—113·5	—119·5
Balance in forebay and reservoir ..		1,603·5	1,603·5	1,436·2	1,322·4	1,202·9	1,084·6	967·5	851·8	747·8	644·2	541·5	986·7	1,002·2	1,548·6	1,381·4	1,267·9	1,148·4
Surplus	..	514·0	38·2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..

Effective reservoir capacity to F.R L. = 1,550 million cubic feet.

TABLE XII—*cont.*

Working table for Pykara No. 1 reservoir for period September 1916—August 1919—*cont.*

(Subsequent to Glen Morgan, Makurti, Porthimund and Sandy Nalla.)

	Million cubic feet.																	
	1918—*cont.*										1919.							
	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.
Pykara flow excluding Makurti and Porthimund basins.	..	62·6	114·2	165·6	85·7	309·0	35·1	94·1	720·3	164·2	38·8	46·4	6·1	81·4	53·1	619·4	1,355·0	585·0
Supply from the Pykara river ..	..	62·6	114·2	165·6	85·7	309·0	35·1	94·1	720·3	164·2	38·8	46·4	6·1	81·4	53·1	619·4	*1,355·0*	*585·0*
Supply from Glen Morgan reservoir.	7·1	..	..	..	..	..	..	.	..	..	..	16·4	7·1	..	..	..	..	..
Supply (and surplus) from Makurti reservoir.	232·1	166·9	100·3	36·9	119·1	..	137·7	109·2	..	..	173·2	169·7	225·3	146·6	172·6	..	*98·63*	*396·5*
Supply (and surplus) from Porthimund reservoir.	33·8	43·5	58·5	70·5	68·2	..	65·2	69·7	..	56·1	61·0	40·5	34·5	45·0	47·3	..	*32·3*	*126·6*
Supply (and surplus) from Sandy Nalla reservoir.	59·8	59·8	59·8	59·8	59·8	23·8	94·8	59·8	*109·1*	59·8 *41·1*	59·8	59·8	59·8	59·8	59·8	..	*344·5*	*27·6*
Total supply available for storage or draft during the month.	332·8	332·8	332·8	332·8	332 8	332·8	332·8	332·8	829·4	321·2	332·8	332·8	332·8	332·8	332·8	619·4	1,830·4	1,135·7
Replenishment from the Pykara reservoir.	118·0	116·9	115·7	103·9	103·4	102·7	101·9	104·2	Nil.	119·2	106·2	107·8	106·1	103·1	101·1	Nil.	Nil.	Nil.
Evaporation	21·8	20·7	19·5	7·7	7·2	6·5	5·7	8·0	13·3	11·4	10·9	11·6	9·9	6·9	4·9	2·0	7·5	11·1
Draw-off for power (165 cusecs) ..	429·0	429·0	429·0	429·0	429·0	429·0	429 0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0	429·0
Accumulated storage or deficit ..	—118·0	—116·9	—116·7	—103·9	—103 4	—102·7	—101·9	—104·2	387·1	—119·2	—106·2	—107·8	—106·1	—103·1	—101·1	188·4	1,393·9	695·6
Balance in forebay and reservoir. ..	1,030·4	913·5	797·8	693·9	590·5	487·8	385·9	281·7	668·8	549·6	443·4	335·6	229·5	126·4	25·3	213·7	1,603·5	1,603·5
Surplus	..	..	..	..	..	..	..	..	..	..	..	.	..	..	..	..	*4·1*	*695·6*

Effective reservoir capacity to F.R.L. = 1,550 million cubic feet.

Table XIII.

Evaporation and absorption losses for Indian Reservoirs.

Extracts from "Facts and Figures" by Buckley, "Control of Water" by Parker, "Storage Reservoirs" by Strange, etc. (Reduced to a monthly basis).

—	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Authority.
						In inches.								
Ekruk tank, Sholapur, Bombay	7·2	6·5	7·2	11·5	11·9	7·0	7·2	7·2	7·0	7·2	7·0	7·2	94·1	Buckley's Facts and figures.
Rajaputana	9·3	8·4	9·3	13·8	14·3	13·8	12·7	12·7	12·3	9·3	9·0	9·3	134·2	Do.
Pashan tank, Poona	5·3	3·9	5·3	8·1	11·8	Not available.				7·8	5·7	4·3	..	Do. (Evaporation loss only).
Foy Sagar reservoir, Ajmere	6·2	5·6	6·2	12·0	12·4	12·0	6·2	6·2	6·0	6·2	6·0	6·2	91·2	Do.
Vehar and Tulsi lakes near Bombay				The average of 8 years gives the yearly loss to be.									45·0	Do.
Bombay Water Works 'Tomlinson' for a reservoir of 300—3,000 acres.	5·0	5·5	6·0	7·5	8·0	5·0	3·0	4·0	4·0	5·0	4·5	5·0	62·5	Do.
Tansa Reservoir, Bombay	4·0	5·6	5·6	6·0	7·8	Not available.								Do.
Panam Lake, Bombay (Proposed)	6·0	9·0	9·0	9·0	9·0	3·0	3·0	3·0	3·0	6·0	6·0	6·0	72·0	Hydro Electric Survey of India Triennial Report—Vol. III, page 80.
Red hills tank, Madras	7·4	6·9	8·1	9·0	11·1	9·0	10·2	9·9	11·4	8·4	8·1	4·0	103·5	Buckley's Facts and figures.
Krishnaraja Sagar reservoir, Mysore	6·6	7·9	8·8	8·7	9·2	7·5	5·2	5·4	6·7	7·1	6·0	5·9	85·1	Cauvery Gauging division.
Storage reservoirs	2·0	2·0	6·0	6·0	6·0	6·0	4·0	4·0	4·0	4·0	2·0	2·0	48·0	Strange's storage reservoirs.
Control of water. Bright sky. 50° mean temperature.	..	..	0·27	foot per month.									38·9	Control of water by Parker, page 191 (Evaporation only).
Control of water. ,, ,, 60° ,,	..	..	0·38	,,	,,	(Average monthly temperature at Pykara is 68° F).							54·7	
Control of water. ,, ,, 85° ,,	..	..	0·77	,,	,,								110·9	
Assumed for Pykara	5·0	7·0	7·0	7·0	7·0	3·0	3·0	3·0	3·0	5·0	6·0	6·0	60·0	

SECTION 4.—HYDRAULIC WORKS.

The original scheme for the hydraulic works drawn up by Mr. B. D. Richards, involved the construction of a high dam above the Pykara Bridge with storage to give an average draft of 144 cusecs. It was proposed to divert this regulated river flow lower down into a flume. This flume was to convey the water to a forebay formed by an earthen bund and masonry dam. From the forebay the water was to be led through an inlet tower and penstocks to the power plant.

The schemes of other engineers who studied this development did not differ radically from the above. In one case, however, the site of the main dam was changed to a location near Wilson's Monument, about half a mile down the river.

In developing a water-power care must be taken to reduce the unproductive part of the investment to a minimum. The capacity should follow the load curve as closely as practically possible. The initial expenditure is thus kept down and the fixed charges are a minimum.

Bearing this in mind, the possibilities of developing the power in two stages over the falls, and of the diversion of the Pykara into other catchments were examined, but were not found as attractive as the original scheme.

Efforts were then made to devise more economical alternatives to the various parts of the original scheme, as it was realized that it involved a large proportion of the investment remaining unproductive for some years.

The dam sites selected above the Pykara Bridge were found, after considerable exploration work, to be economically unsuitable for high structures. The location selected lower down near the Wilson's Monument, is a fairly good dam site, but a poor site for a reservoir when compared with other sites in the catchment. There was also the possibility at full reservoir level of serious *seepage—even piping*—through the low saddles on the left flank of the structure.

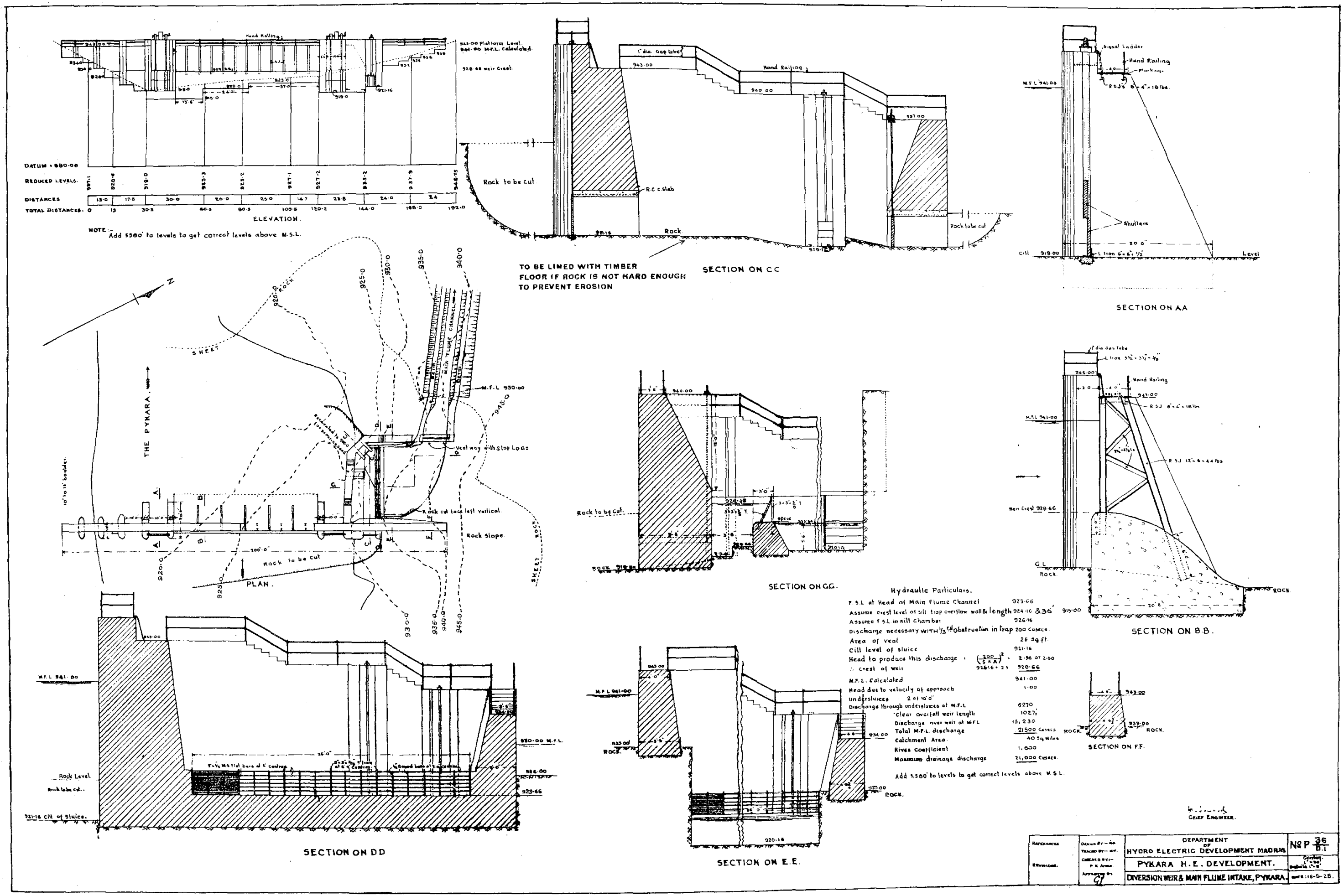
The results of these studies indicated that, in general, owing to the formation of the ground in the catchment high dams could only be constructed at a high cost on account of expensive foundations, whereas conditions were much more favourable for lower structures.

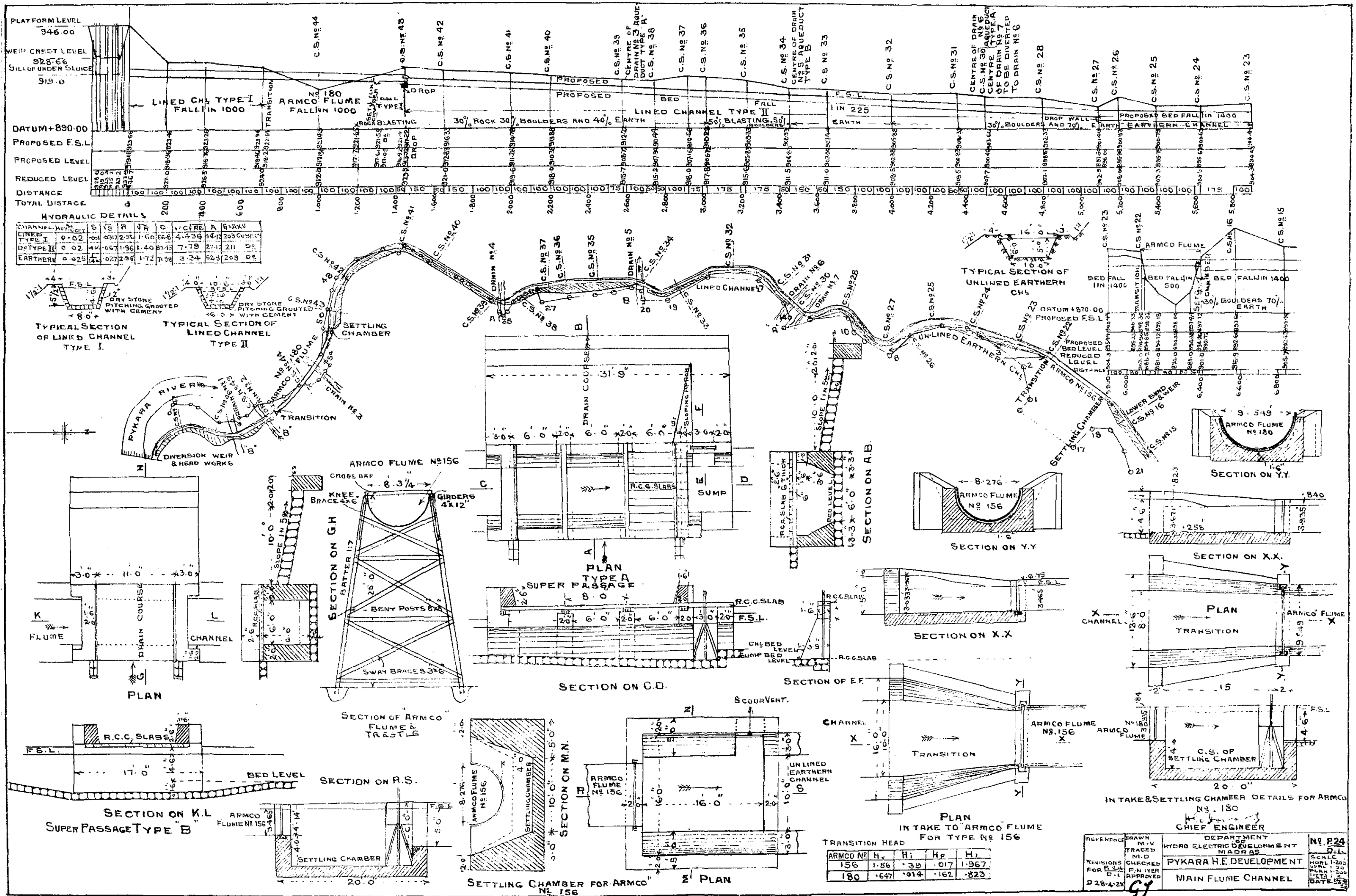
Several new and favourable sites for lower dams and smaller reservoirs were located, and a storage system designed, by stages, to meet the estimated increasing load demand. These storages are described in another section. The remainder of the hydraulic lay-out is very similar to the original, differing only in design details.

Diversion Dam and Intake.—The site is a good one with bed rock on both sides and in the bed of the stream. Just beyond the toe of the structure, there is a sudden fall in the river which will form a good 'get away' for any flood waters, and provide a natural protection to the intake. The whole structure has been redesigned, and is simpler and less costly than the one described in the Introductory Report. It is shown on plan No. $\frac{\text{P.36}}{\text{D-1}}$. Care has been taken that the crest of the inlet weir will be unaffected by the highest flood level. It will be noticed that the intake can be kept clean at all times, while practically no sediment or matter in suspension can enter the main aqueduct. By means of the main sluice gates the course of the stream can be controlled and deposits of gravel and sand prevented.

The Main Aqueduct shown on plan No. $\frac{\text{P.24}}{\text{D-1}}$ is 6,840 feet in length. A large part of the section is to be lined. The capacity of the aqueduct has been fixed at 200 cusecs, and suitable spillways and scour gates have been provided.

The flow under normal operating conditions need not exceed the designed maximum continuous flow of 150 cusecs, but there may be times, when it would be desirable to increase the water level in the forebay at a quicker rate. It might be argued that the capacity should be equal to the maximum rate of consumption, which is 300 cusecs. It is, however, considered that this would involve too much idle capacity and unproductive investment. Further the Glen Morgan flume feeding the forebay at the other end has been designed to carry 100 cusecs, and this together with the 200 cusecs from the main aqueduct will make up the supply required at peak load.


ELEVATION.
DATUM + 880.00
REDUCED LEVELS.
DISTANCES
TOTAL DISTANCES.
NOTE:- Add 5560' to levels to get correct levels above M.S.L.
944.00 Platform Level.
941.00 M.F.L. Calculated.
928.66 weir Crest.
Hand Railing
SECTION ON CC
Rock to be cut
R.C.C slab
Rock
Rock to be cut
TO BE LINED WITH TIMBER FLOOR IF ROCK IS NOT HARD ENOUGH TO PREVENT EROSION
SECTION ON AA
Signal Ladder
Hand Railing
Planking
Shutters
Level
THE PYKARA
PLAN.
Rock to be cut
Rock slope
Rock cut face left vertical
Veat way with Stop Logs
MAIN FLUME CHANNEL
M.F.L 950.00
SHEET ROCK
SECTION ON GG.
Rock to be cut
SECTION ON B.B.
Hand Railing
Weir Crest 928.66
ROCK
SECTION ON DD
M.F.L 941.00
Rock Level
Rock to be cut
921.16 Cill of Sluice
SECTION ON E.E.
SECTION ON F.F.
Hydraulic Particulars.
F.S.L at Head of Main Flume Channel 923.66
Assume crest level of silt trap overflow wall & length 924.16 & 36' 915.00
Assume F.S.L in silt chamber 926.16
Discharge necessary WITH 1/3rd obstruction in trap 200 Cusecs.
Area of vent 25 Sq ft.
Cill level of sluice 921.16
Head to produce this discharge = (200 / 5 × A)² = 2.56 or 2.50
∴ crest of weir 926.16 + 2.5 928.66
M.F.L. Calculated 941.00
Head due to velocity of approach 1.00
Undersluices 2 at 10'0"
Discharge through undersluices at M.F.L 6270
Clear overfall weir length 102½'
Discharge over weir at M.F.L 15,230
Total M.F.L. discharge 21500 Cusecs
Catchment Area 40 Sq Miles
River coefficient 1,800
Maximum drainage discharge 21,000 Cusecs.
Add 5,580' to levels to get correct levels above M.S.L.
Chief Engineer.
References
Revisions.
Drawn By
Traced By
Checked By
Approved By
DEPARTMENT OF HYDRO ELECTRIC DEVELOPMENT MADRAS
No P 36/B.1
PYKARA H.E. DEVELOPMENT.
DIVERSION WEIR & MAIN FLUME INTAKE, PYKARA.
Date: 18-5-28.



HYDRAULIC DETAILS

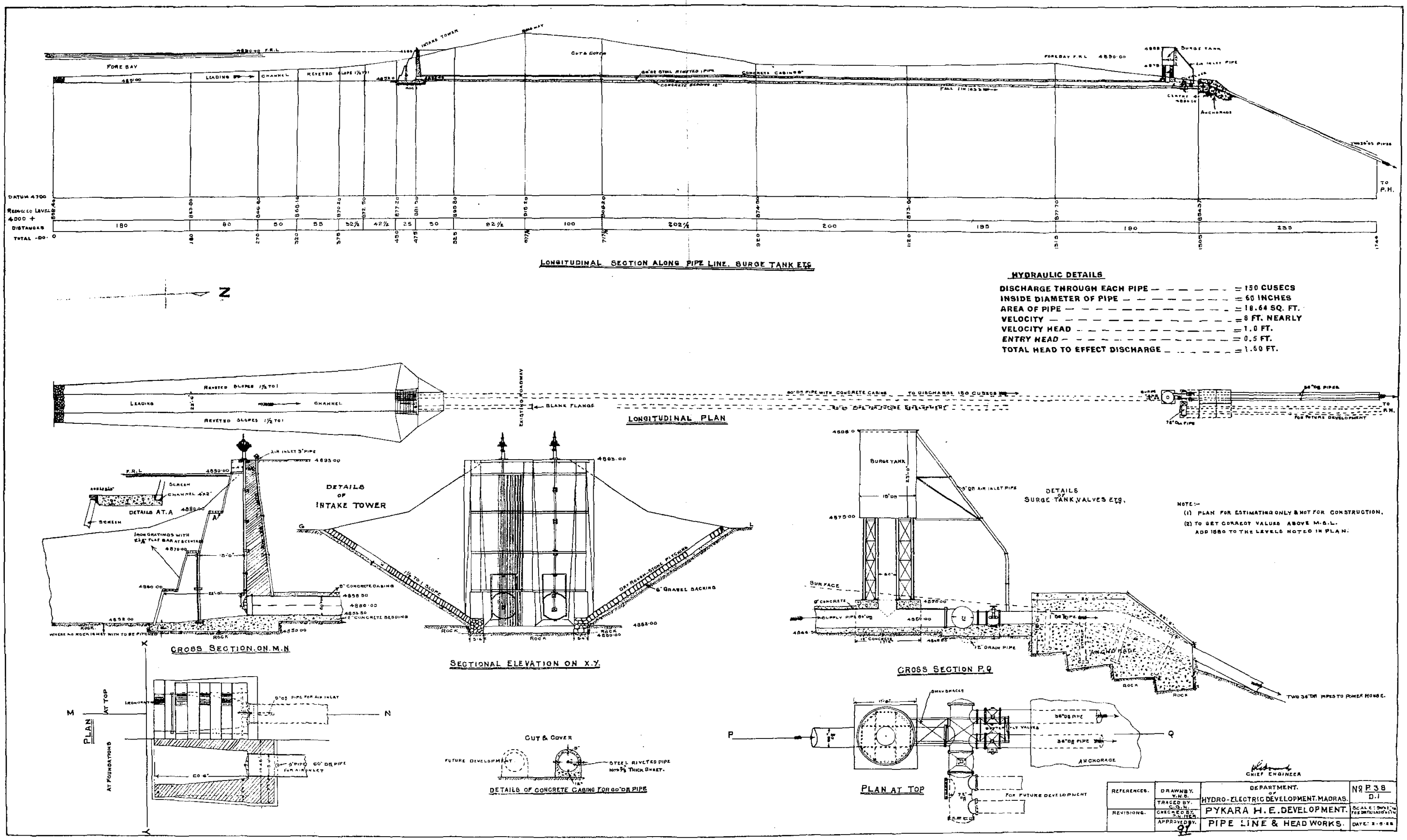
CHANNEL	RUT. COEF.	S	√S	R	√R	C	V=C√RS	A	Q=AXV
LINED TYPE I	0.02	.001	.0317	2.56	1.60	66.8	4.436	46.12	203 CUSECS
Do TYPE II	0.02	.004	.067	1.96	1.40	83.43	7.79	27.12	211 Do
EARTHERN	0.025	1/1400	.027	2.95	1.72	71.98	3.34	62.3	209 Do

TRANSITION HEAD

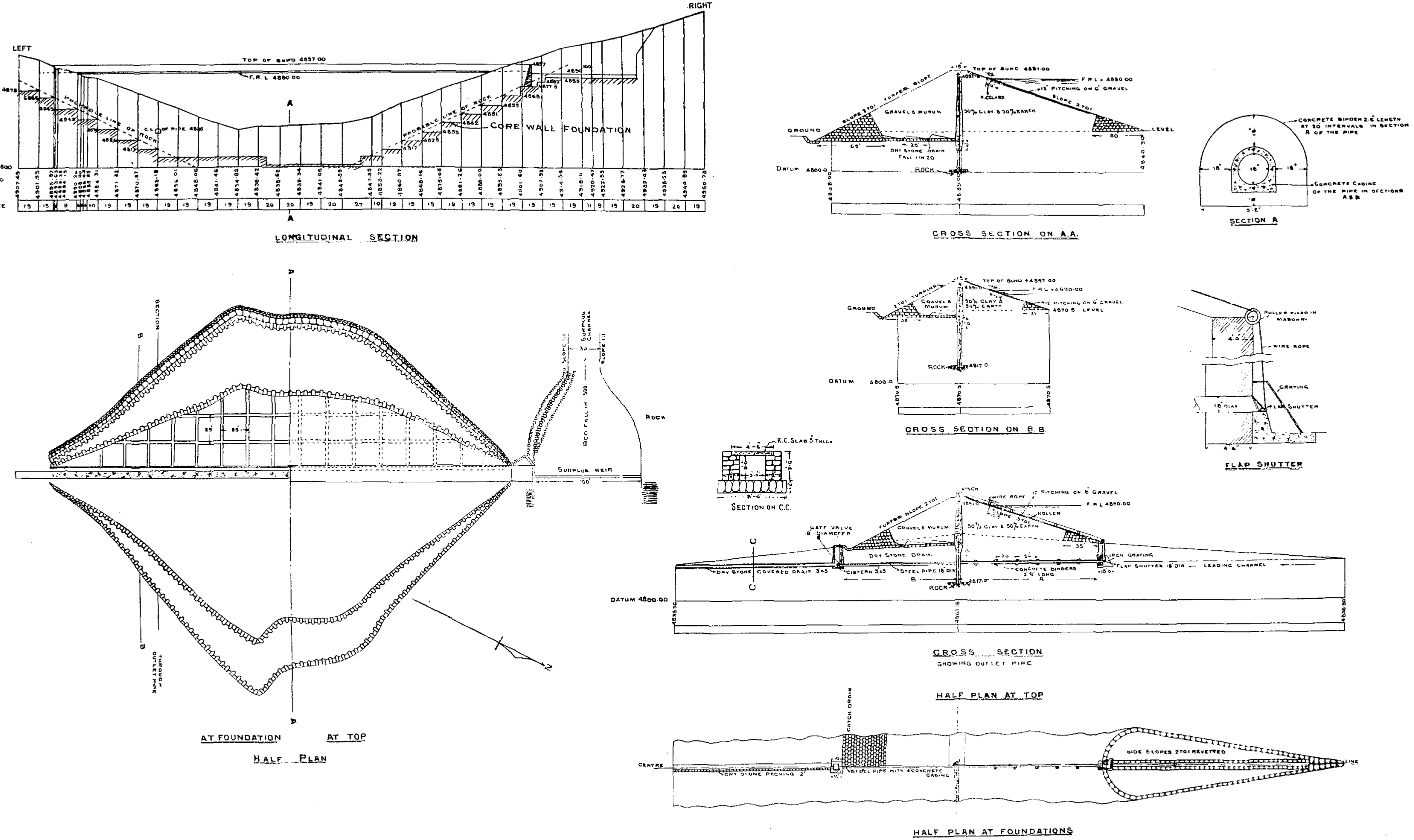
ARMCO No	H_v	H_i	H_f	H_t
156	1.56	.39	.017	1.967
180	.647	.014	.162	.823

REFERENCE	DRAWN M.V. TRACED M.D. CHECKED F.N. IYER APPROVED	DEPARTMENT OF HYDRO ELECTRIC DEVELOPMENT MADRAS	No P24 D.L.
REVISIONS FOR P.24 D.L. D 28-4-28		PYKARA H.E. DEVELOPMENT	SCALE HORL. 1"-200 VERL. 1"-20 PLAN 1"-200 DETAILS
		MAIN FLUME CHANNEL	DATE

61



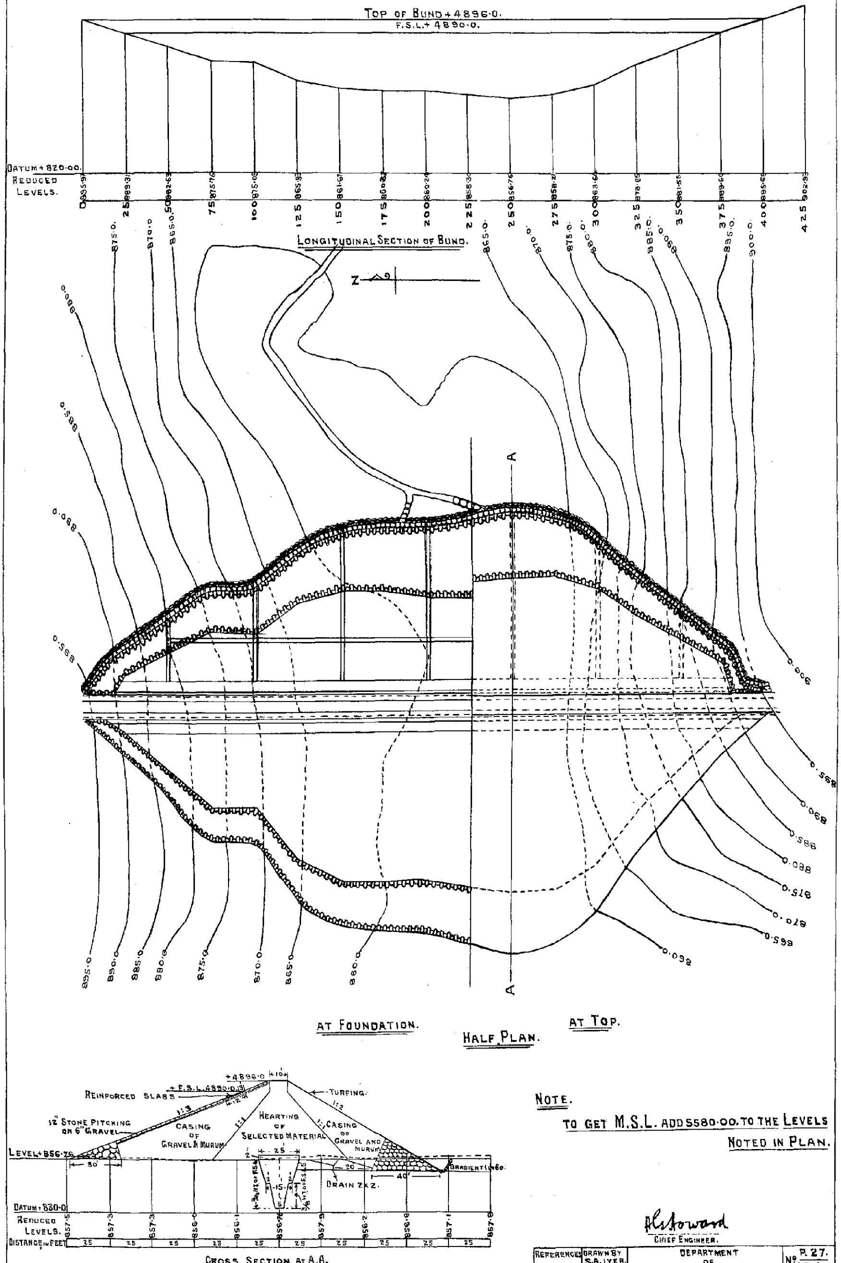
LONGITUDINAL SECTION ALONG PIPE LINE, SURGE TANK ETC.
FORE BAY
LEADING CHANNEL
REVETED SLOPE 1½ TO 1
INTAKE TOWER
CUT & COVER
CONCRETE CASING 8"
FORE BAY F.R.L 4890.00
SURGE TANK
AIR INLET PIPE
ANCHORAGE
TO P.H.
DATUM 4700
REDUCED LEVEL 4000 +
DISTANCES
TOTAL -DO-
HYDRAULIC DETAILS
DISCHARGE THROUGH EACH PIPE = 150 CUSECS
INSIDE DIAMETER OF PIPE = 60 INCHES
AREA OF PIPE = 19.64 SQ. FT.
VELOCITY = 8 FT. NEARLY
VELOCITY HEAD = 1.0 FT.
ENTRY HEAD = 0.5 FT.
TOTAL HEAD TO EFFECT DISCHARGE = 1.50 FT.
N
REVETED SLOPES 1½ TO 1
LEADING CHANNEL
EXISTING ROADWAY
BLANK FLANGE
TO DISCHARGE 150 CUSECS
LONGITUDINAL PLAN
FOR FUTURE DEVELOPMENT
TO P.H.
DETAILS OF INTAKE TOWER
AIR INLET 5" PIPE
4895.00
F.R.L
4890.00
SCREEN
CHANNEL 4"x2"
DETAILS AT A
4880.00
4870.00
15'-0"
4860.00
4852.00
ROCK
CROSS SECTION ON M.N
G
L
1½ TO 1 SLOPE
DRY ROUGH STONE PITCHING
6" GRAVEL BACKING
ROCK
SECTIONAL ELEVATION ON X.Y.
DETAILS SURGE TANK, VALVES ETC.
SURGE TANK
4875.00
SURFACE
SUPPLY PIPE 60"DR
12" DRAIN PIPE
ANCHORAGE
ROCK
TWO 36"DR PIPES TO POWER HOUSE.
CROSS SECTION P.Q
NOTE:-
(1) PLAN FOR ESTIMATING ONLY & NOT FOR CONSTRUCTION.
(2) TO GET CORRECT VALUES ABOVE M.S.L. ADD 1580 TO THE LEVELS NOTED IN PLAN.
X
M
N
Y
PLAN
AT TOP
AT FOUNDATIONS
6"DR PIPE FOR AIR INLET
60" DR PIPE
CUT & COVER
FUTURE DEVELOPMENT
STEEL RIVETED PIPE
DETAILS OF CONCRETE CASING FOR 60" DR PIPE
P
Q
36"DR PIPE
ANCHORAGE
FOR FUTURE DEVELOPMENT
PLAN AT TOP
CHIEF ENGINEER
REFERENCES.
REVISIONS.
DRAWN BY. Y.N.S.
TRACED BY. C.G.N.
CHECKED BY. P.N. IYER
APPROVED BY.
DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS.
PYKARA H. E. DEVELOPMENT.
PIPE LINE & HEAD WORKS.
No P.38 / D.I
DATE: 2-6-28



NOTE ADD 1580 TO OBTAIN THE CORRECT VALUES ABOVE M.S.L.

CHIEF ENGINEER

REFERENCES	DRAWN BY M. RADHAKRISHNA	DEPARTMENT OF HYDRO ELECTRIC DEVELOPMENT MADRAS	No P.28 / D.I.
REVISIONS	TRACED BY M. DHANAKOTY		
	CHECKED BY P.N. IYER	PYKARA H.E. DEVELOPMENT	SCALE 1"=40 FT
	APPROVED	MAIN - FOREBAY. LOWER BUND	DATE 12.3.28



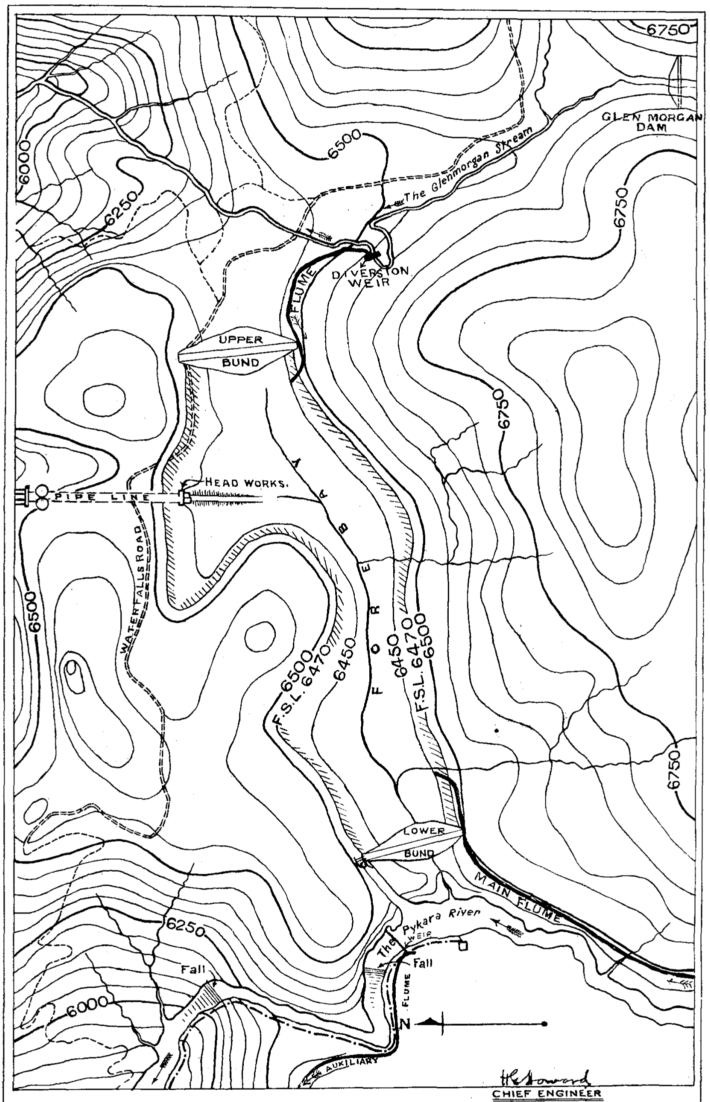
Note.

To get M.S.L. add 5580·00 to the Levels Noted in Plan.

Chief Engineer.

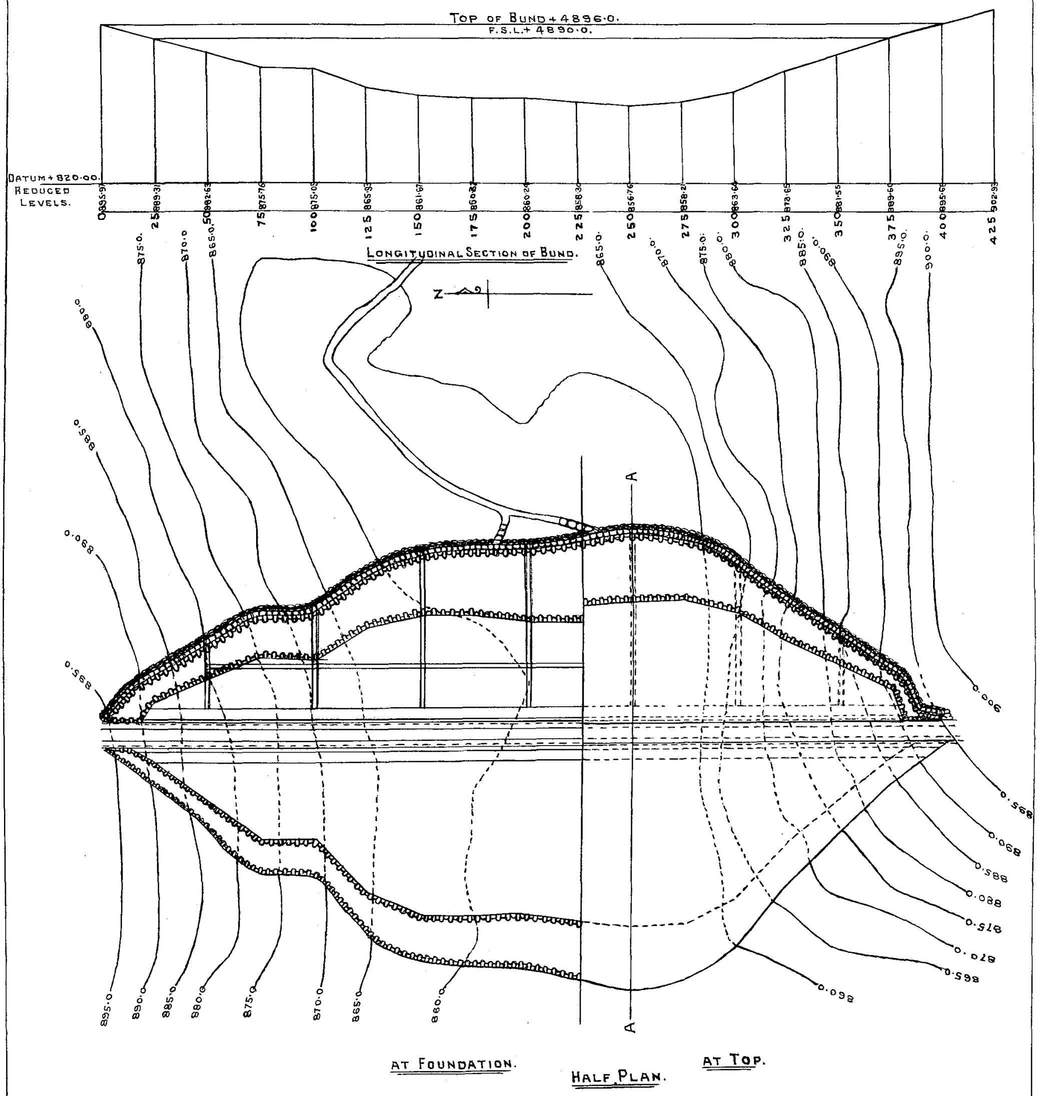
References	Drawn by S.A.Iyer.	Department of Hydro-Electric Development Madras.	No. P.27. D.1.
	Traced by P.C.R.M.		Scale 1 inch 20 Ft.
Revisions	Checked by P.N.Iyer	Pykara H.E. Development.	
	Approved by	Main Forebay Upper Bund	Date: 28/5/28

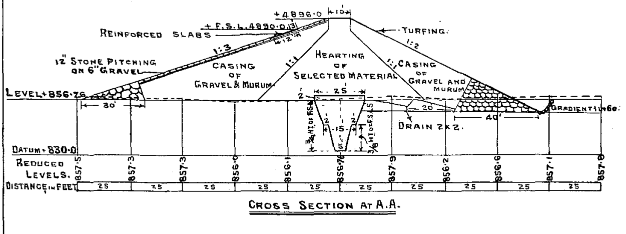
91



H.C. Howard
CHIEF ENGINEER

REFERENCES	DRAWN BY	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT. MADRAS	No. P.37/F.1
	TRACED BY		
REVISIONS	CHECKED BY P.N. Iyer	PYKARA.H.E. DEVELOPMENT.	SCALE: 8 Inches=1 M.
	APPROVED BY	TOPOGRAPHY OF MAIN FOREBAY	DATE: 18-5-28





NOTE.

TO GET M.S.L. ADD 5580·00. TO THE LEVELS NOTED IN PLAN.

H. Stoward
CHIEF ENGINEER.

REFERENCES	DRAWN BY S.A. IYER. / TRACED BY P.C.P.M.	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT MADRAS.	No. P. 27. / D. 1.
REVISIONS	CHECKED BY P.N. IYER / APPROVED BY	PYKARA H.E. DEVELOPMENT. / MAIN FOREBAY UPPER BUND	SCALE:- 1 INCH 20 FT. / DATE:- 28/5/28

91

and deposits of sediment. The bottom and sides of the approach are to be lined with dry pitching. The tower is a concrete structure with the usual screens and a simple sluice gate. Provision is to be made for another gate to be installed at some future date. In front of the racks, grooves are provided for flash boards. The foundations will be built on rock and cut off walls extended on each side.

From the tower two 5 feet pipes are to be laid in cut and cover section for about 1,000 feet. The pipes will be laid on a 12 inches concrete mat, and protected with a 9 inches thickness of concrete all round. One pipe only will be laid at first, but a short length of the other will be laid next to the tower, in order to facilitate the installation of the second one at some future date.

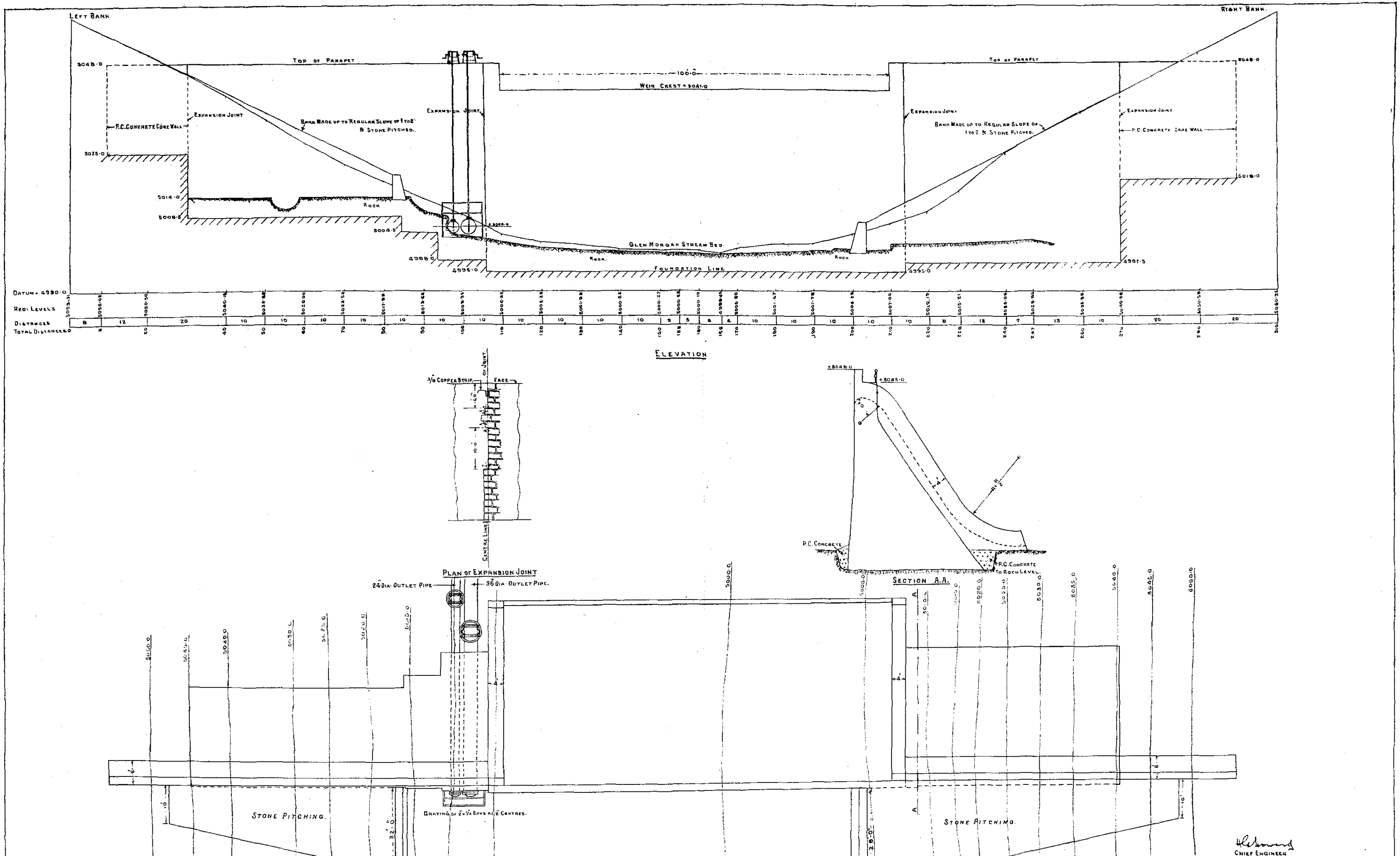
At the end of each pipe a drain valve is to be provided, and a surge chamber erected of the dimensions shown. The final details of the surge chamber can only be decided after the characteristics of the impulse wheels and the length and diameter of the penstocks are definitely known. The pipes will be connected to a common header from which two—eventually four—penstocks will be taken. This header will be separated into two sections by a valve, but it is not considered necessary to go to the expense of providing each of the 5 feet pipes with a valve at the header end.

Glen Morgan Dam.—This will be constructed of rubble masonry in cement mortar. Preliminary investigations indicated that this type of dam will be cheaper and more convenient than an earthen bund. Important outlet works are necessary, plenty of stone is available near by, and the flood and surplus waters are best discharged over the structure. These are some of the factors which rendered the consideration of a masonry structure in preference to one of earth. The estimates for a cement concrete structure were also prepared, but were found higher than for one of rubble masonry. The estimated flood discharge is given in the section on hydrology as 1,300 cusecs. To take care of this water, estimates were prepared for an overflow section 100 feet long, a similar but lower section with crest gates, and a third with a shorter section and syphons.

There was very little difference between the costs of the first and last design, and it was eventually decided to adopt the straight overflow section as being the more suitable. The design is simpler and there will be less liability of erosion at the toe of the dam. A standard outlet, of steel pipes embedded in concrete with a flap valve on the reservoir side and a gate or needle valve for regulation on the down-stream side, is proposed for all dams. This combination is simple to operate and the cost is low. For Glen Morgan a maximum draw-off of 100 cusecs is assumed. Two outlet pipes are projected, one of 24″ and one of 36″. The latter may probably be used, at some future date, to connect directly with the header at the penstocks, by means of a pipe line. It will then be possible to carry about 15,000 Kw. at Pykara Power House, independent of the forebay, should it ever be necessary to empty the latter. If this design is adopted a valve must be installed at the header end of the future 5 feet pipe line communicating with the forebay. Exploration of the ground for the foundations of Glen Morgan Dam is nearly complete, and the design of the structure is shown on Drawings Nos. $\frac{\text{P.-21}}{\text{D-1}}$ and $\frac{\text{P.-21-A}}{\text{D-1}}$.

No detailed designs have yet been drawn up for any of the other dams, all the estimates being based on standard profiles as shown on the drawings, and which are on file for reference. This will ensure reasonably close estimates. The dams will not be needed for some years so that, beyond a certain amount of exploration work at each site in order to determine the feasibility of the site and the extent of the foundations, it does not seem justifiable to incur any further expense.

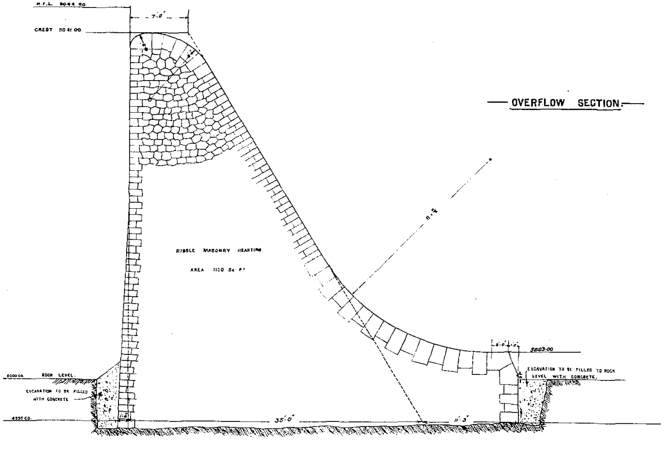
Glen Morgan Flume.—This has been designed for a maximum capacity of 100 cusecs. The design is shown on drawing No. $\frac{\text{P. 40}}{\text{D. 1}}$, and has been made as simple as possible. The intake aperture may be submerged when the dam is spilling during high floods; it will, however, be protected with flash-boards and any excess water entering the flume will be discharged by suitable waste weirs. The flume is 1,400 feet long, and two scour gates are provided. At each gate the bed of the flume is lowered by about 12 inches for a distance of 20 feet and lined with masonry, in order to facilitate the deposit of any sediment in the water.



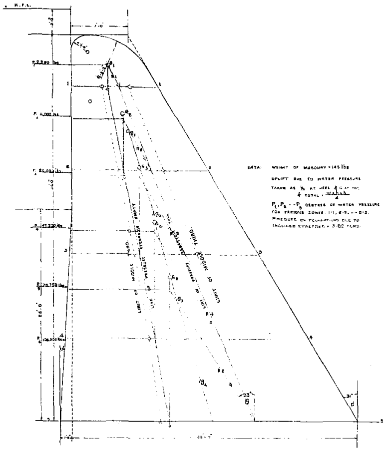
Chief Engineer

References	Drawn By.	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT, MADRAS.	No. P. 21. / D.I.
	Traced By. R. Paramasivan		
Revisions for Plan No. P.21/B.1. Date:- 23-4-28	Checked By. P.N. Iyer.	PYKARA H. E. DEVELOPMENT.	Scale:- 1 inch to 10 feet.
	Approved By.	GLEN MORGAN DAM	Date:- 19-6-28.

OVERFLOW SECTION.



CROSS SECTION.



DATA: WEIGHT OF MASONRY = 145 lbs

UPLIFT DUE TO WATER PRESSURE TAKEN AS ½ AT HEEL & 0 AT TOE & TOTAL = $\frac{w \times h \times b}{4}$

$P_1, P_2 - - P_5$ CENTRES OF WATER PRESSURE FOR VARIOUS ZONES 1-1, 2-2, - - 5-5.

PRESSURE ON FOUNDATIONS DUE TO INCLINED STRESSES = 3.82 TONS.

STRESS DIAGRAM.

CONDITIONS OF STABILITY.

1 OVERTURNING – MOMENT OF WATER PRESSURE AT TOE = 74,750 × 13¾ Ft. lbs
" OF DAM WEIGHT (½ UPLIFT) = 82,250 × 23¼ Ft. lbs
HENCE SAFE AGAINST OVERTURNING

2 MAXIMUM INTENSITY OF PRESSURE IN MASONRY.– (VERTICAL COMPRESSIVE STRESSES)

(a) FOR RESERVOIR FULL AT TOE = [illegible]
= 5983 lbs OR 2.7 TONS PER Sq. Ft.

(b) FOR RESERVOIR EMPTY AT HEEL = [illegible]
= 6941.90 OR 3.10 TONS PER Sq. Ft.

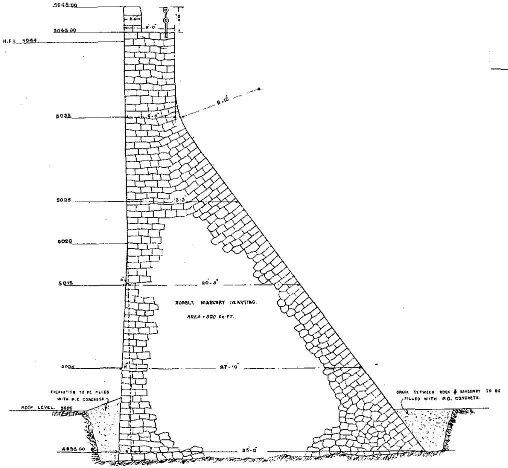
3 INCLINATION OF R5 TO NORMAL θ = 33° TAN θ = 0.65
COEFFICIENT OF FRICTION FOR MASONRY ON MASONRY & MASONRY ON ROCK FOUNDATIONS BEING USUALLY TAKEN AS RANGING FROM .6 TO .75 TAN θ IS WITHIN LIMITS, HENCE THIS CONDITION TOO IS SATISFIED.

4 MAXIMUM INCLINED STRESSES.– φ BEING 31° AND < θ BOUVIER'S FORMULA
$P_i = P_v \sec^2 \theta$ IS BEING USED.

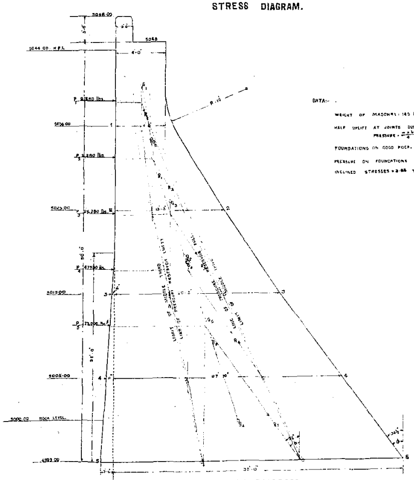
HENCE INCLINED STRESS AT TOE (FOR RESERVOIR FULL) = 2.7 × SEC² 33° = 2.7 × (1.19)² = 3.82 TONS PER Sq. Ft.

HENCE INCLINED STRESS AT HEEL (FOR RESERVOIR EMPTY) = 3.10 SEC² 3° = 3.10 × (1.0014)² = 3.1 TONS

GRAVITY SECTION.



CROSS SECTION.



DATA:–

WEIGHT OF MASONRY = 145 lbs PER CFT.

HALF UPLIFT AT JOINTS DUE TO WATER PRESSURE = $\frac{w \times h \times b}{4}$ lbs.

FOUNDATIONS ON GOOD ROCK. MAXIMUM PRESSURE ON FOUNDATIONS DUE TO INCLINED STRESSES = 3.64 TONS.

STRESS DIAGRAM.

CONDITIONS OF STABILITY

1 OVERTURNING – MOMENT OF WATER PRESSURE AT TOE = 75,000 × 16⅔
= 12,25,000 lb. Ft.
" " MASONRY " " " = 1,01,630 × 24⅔
= 24,89,835 lb. Ft.
HENCE SAFE AGAINST OVERTURNING.

2 MAXIMUM INTENSITY OF PRESSURE:–
(a) AT TOE FOR RESERVOIR FULL = [illegible]
= 5310 lbs OR 2.37 TONS PER Sq. Ft.

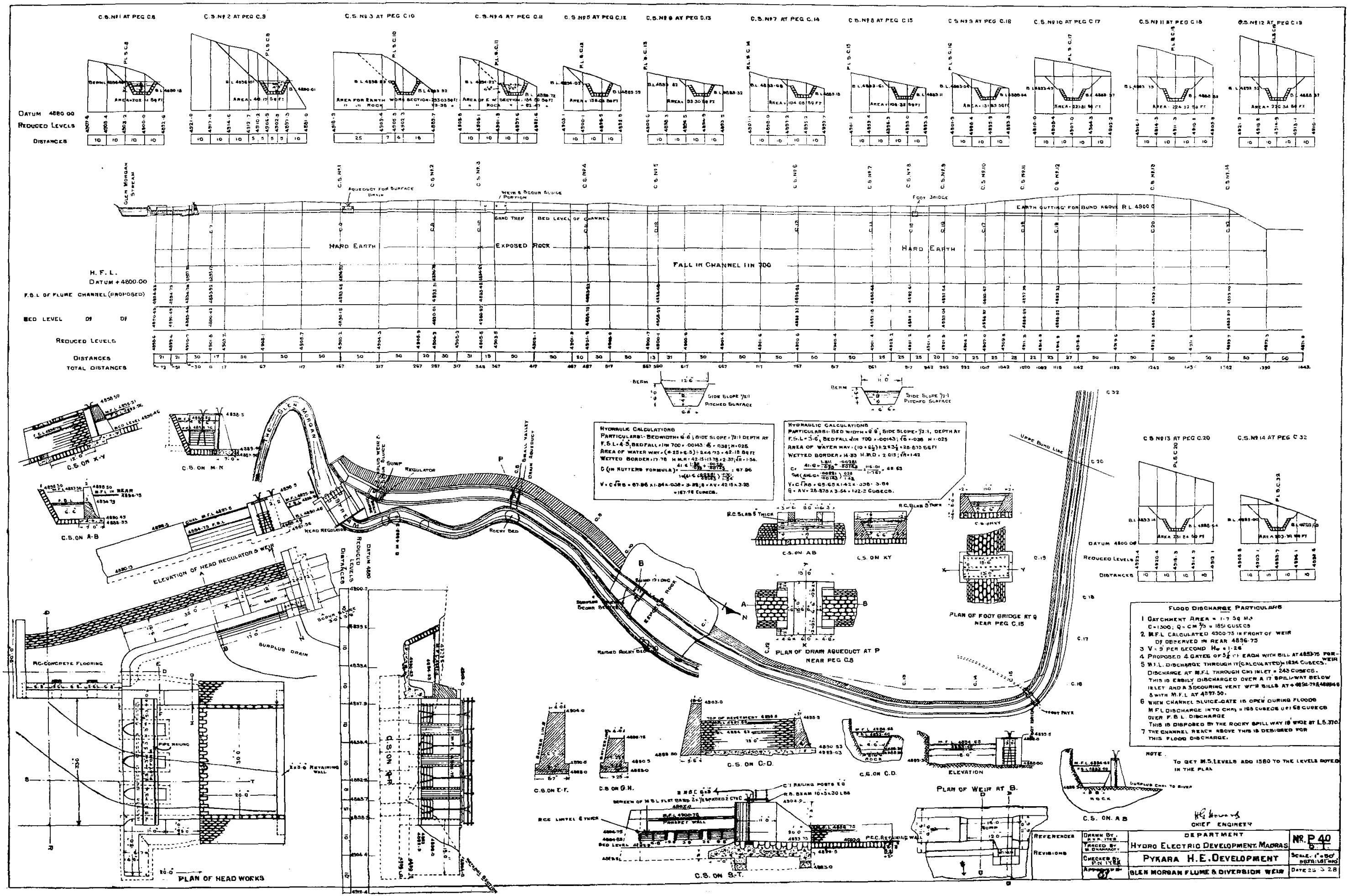
(b) AT HEEL FOR RESERVOIR EMPTY = [illegible]
= 7,133 lbs OR 3.1 TONS PER Sq. Ft.

3 INCLINATION OF R_5 TO NORMAL = θ = 36° & θ = .72
COEFFICIENT OF FRICTION FOR MASONRY AND MASONRY ON ROCK FOUNDATIONS ASSUMED .6 TO .75

4 INCLINED STRESSES – φ BEING 36½° & GREATER THAN θ, BOUVIER'S FORMULA
$P_i = P_v \sec^2 \phi$ IS USED.
∴ P_i AT TOE = 2.37 × SEC² 36½° = 3.64 TONS PER Sq. Ft. (FOR RESERVOIR FULL)
P_i AT HEEL = 3.1 × SEC² 3° = 3.1 × (1.0014)² = 3.1 TONS PER Sq. Ft. (FOR RESERVOIR EMPTY)

CHIEF ENGINEER

REFERENCES	DRAWN BY, V. H. Sm	DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT MADRAS	Nº P 21A / 11
	TRACED BY, A. A.		
REVISIONS FOR PLAN Nº P21/81 DATED 23-4-28	CHECKED BY, P. R. IYER.	PYKARA H. E. DEVELOPMENT.	SCALE 1 INCH TO 10 FEET
	APPROVED BY,	GLEN MORGAN DAM.	DATE 18-4-28



C.S. Nº 1 AT PEG C.8
C.S. Nº 2 AT PEG C.9
C.S. Nº 3 AT PEG C.10
C.S. Nº 4 AT PEG C.11
C.S. Nº 5 AT PEG C.12
C.S. Nº 6 AT PEG C.13
C.S. Nº 7 AT PEG C.14
C.S. Nº 8 AT PEG C.15
C.S. Nº 9 AT PEG C.16
C.S. Nº 10 AT PEG C.17
C.S. Nº 11 AT PEG C.18
C.S. Nº 12 AT PEG C.19
DATUM 4880.00
REDUCED LEVELS
DISTANCES
GLEN MORGAN STREAM
AQUEDUCT FOR SURFACE DRAIN
WEIR & SCOUR SLUICE PORTION
FOOT BRIDGE
EARTH CUTTING FOR BUND ABOVE R.L. 4900.0
SAND TRAP
BED LEVEL OF CHANNEL
HARD EARTH
EXPOSED ROCK
FALL IN CHANNEL 1 IN 700
H.F.L.
DATUM + 4800.00
F.S.L. OF FLUME CHANNEL (PROPOSED)
BED LEVEL
TOTAL DISTANCES
SIDE SLOPE ½:1 PITCHED SURFACE
HYDRAULIC CALCULATIONS
C.S. ON X-Y
C.S. ON M-N
C.S. ON A-B
ELEVATION OF HEAD REGULATOR & WEIR
HEAD REGULATOR
REGULATOR
SURPLUS DRAIN
RC CONCRETE FLOORING
PLAN OF HEAD WORKS
C.S. ON R-R
SMALL VALLEY DRAIN AQUEDUCT
ROCKY BED
RAISED ROCKY BED
R.C. SLAB 5" THICK
PLAN OF DRAIN AQUEDUCT AT P NEAR PEG C.8
PLAN OF FOOT BRIDGE AT Q NEAR PEG C.15
C.S. ON E-F
C.S. ON G.H.
C.S. ON C-D.
C.S. ON S-T.
ELEVATION
PLAN OF WEIR AT B.
UPPER BUND LINE
C.S. Nº 13 AT PEG C.20
C.S. Nº 14 AT PEG C.32
FLOOD DISCHARGE PARTICULARS
1 CATCHMENT AREA = 1.7 SQ MS
C=1300; Q=CM⅔ = 1851 CUSECS
2. M.F.L. CALCULATED 4900.75 IN FRONT OF WEIR
DO OBSERVED IN REAR 4896.75
3 V = 9' PER SECOND Hv = 1.26'
4 PROPOSED 4 GATES OF 5½' C.C. EACH WITH SILL AT 4893.75 FOR WEIR
5 M.F.L. DISCHARGE THROUGH IT (CALCULATED) = 1624 CUSECS.
DISCHARGE AT M.F.L. THROUGH CHL INLET = 243 CUSECS.
THIS IS EASILY DISCHARGED OVER A 17' SPILLWAY BELOW INLET AND A 3' SCOURING VENT WITH SILLS AT + 4894.79 & 4888.46 & WITH M.F.L. AT 4897.50.
6 WHEN CHANNEL SLUICE-GATE IS OPEN DURING FLOODS M.F.L. DISCHARGE INTO CHNL = 166 CUSECS i.e. 68 CUSECS OVER F.S.L. DISCHARGE
THIS IS DISPOSED BY THE ROCKY SPILL WAY 18' WIDE AT L.S. 370.
7 THE CHANNEL REACH ABOVE THIS IS DESIGNED FOR THIS FLOOD DISCHARGE.
NOTE. TO GET M.S. LEVELS ADD 1580 TO THE LEVELS NOTED IN THE PLAN
SURPLUS CHNL TO RIVER
ROCK
C.S. ON. A B
CHIEF ENGINEER
REFERENCES
REVISIONS
DRAWN BY K.V.R. IYER
TRACED BY M. DHANAKOTY
CHECKED BY P.N. IYER
APPROVED BY
DEPARTMENT
HYDRO ELECTRIC DEVELOPMENT, MADRAS
Nº P 40
PYKARA H.E. DEVELOPMENT
GLEN MORGAN FLUME & DIVERSION WEIR
SCALE 1" = 50'
DATE 25-3-28

Buildings.—Provision is made in the estimates for certain permanent buildings to be erected during the period of construction. Others will be added later as the operating revenue increases. The original estimates allowed for a more elaborate construction programme. It is, however, considered that many of the junior operating employees can live quite comfortably, for some time, in the accommodation to be provided for the construction personnel.

The permanent buildings which it is proposed to construct in the first two years are as follows :—

One bungalow for Resident Engineer.
Two similar, but smaller, buildings for other officials.
Three two-family cottages for first-class operators.
Three two-family cottages for second-class operators.
One block of six quarters, each consisting of three rooms.
One small hospital.
One store-house.
One garage.
Two small two-family cottages.

The remainder of the permanent accommodation is to be constructed from the materials utilized for the temporary camp.

The estimates include an allowance for water-supply and drainage, electric lighting, enclosures and grounds.

Plans of representative buildings were obtained from the Consulting Architect's office and other sources as a basis for the estimates, but the final plans will be worked out in greater detail.

The camp has already been tentatively laid out with most of the buildings near the forebay.

It is quite possible, however, that it may be decided to erect the operators' cottages on a site some 1,500 feet above the power-house.

Malarial fever is very prevalent in the vicinity of the power-house site, but, given a good water-supply and modern hygienic facilities, it should be possible to make the locality quite healthy.

Temporary camp.—The estimates include the necessary warehouses and tool sheds, offices, shops, coolie lines, and first-aid hospitals. Quarters are also provided for junior engineers and a few policemen. On account of the high salvage value of corrugated iron sheets it is proposed to use this material with a timber frame-work for most of the structures. The coolie lines and supervisors' quarters will be constructed somewhat similar to those on some of the Nilgiri tea estates.

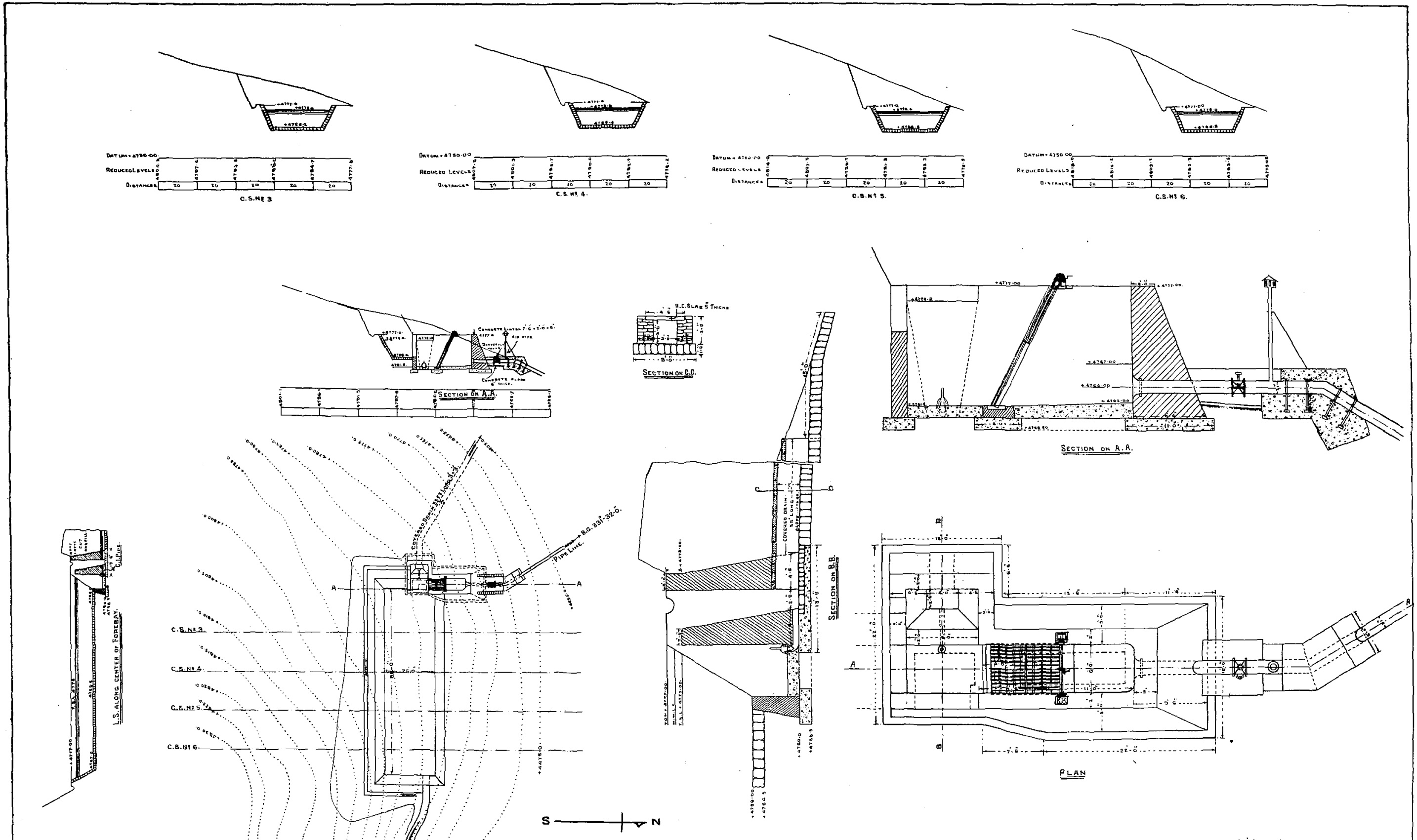
Estimates.—The estimates for the hydraulic works are given in Table XIV, page 30.

TABLE XIV.

Estimate for Hydraulic Works.

Year of operation.	1st.	3rd.	After 10th.	
Continuous KW.	4,000	20,000	22,500	30,000
	RS.	RS	RS.	RS.
Dams—				
Glen Morgan	3,14,000	..	..	..
Makurti	..	10,80,000	..	..
Porthimund	..	..	8,90,000	..
Sandy Nalla	..	..	..	20,00,000 *
Pykara	..	..	..	29,50,000 *
Main Diversion dam	1,20,000	..	..	..
Flume	1,40,000	..	..	..
Glen Morgan flume	38,000	..	..	..
Forebay—				
Upper Bund	76,000	..	..	..
Lower ,, ...	3,60,000	..	..	..
Spillway	20,000	..	..	..
Headworks	3,15,000	..	..	..
Permanent building and services	4,94,000	4,600	4,600	..
Sub-total ..	18,77,000	10,84,600	8,94,600	..
Contingencies	93,900	54,300	44,800	..
Construction plant and tools	3,90,600	60,000	45,000	..
Temporary camp	2,24,600	45,000	40,000	..
Auxiliary power installation	3,02,500	..	..	..
Lines and transformers	1,09,000	42,100	38,000	..
Roads and bridges	5,62,800 }	..	..	..
Land and preliminary work	3,06,000 }			..
Local general expenses	8,55,000	3,20,000	2,65,600	..
Sub-total ..	47,15,400	16,06,000	13,28,000	..
Deduct—Salvage—Auxiliary plant and construction equipment	— 1,77,000	..	..	..
Net cost	45,38,400	16,06,000	13,28,000	49,50,000 *

* Tentative estimates.

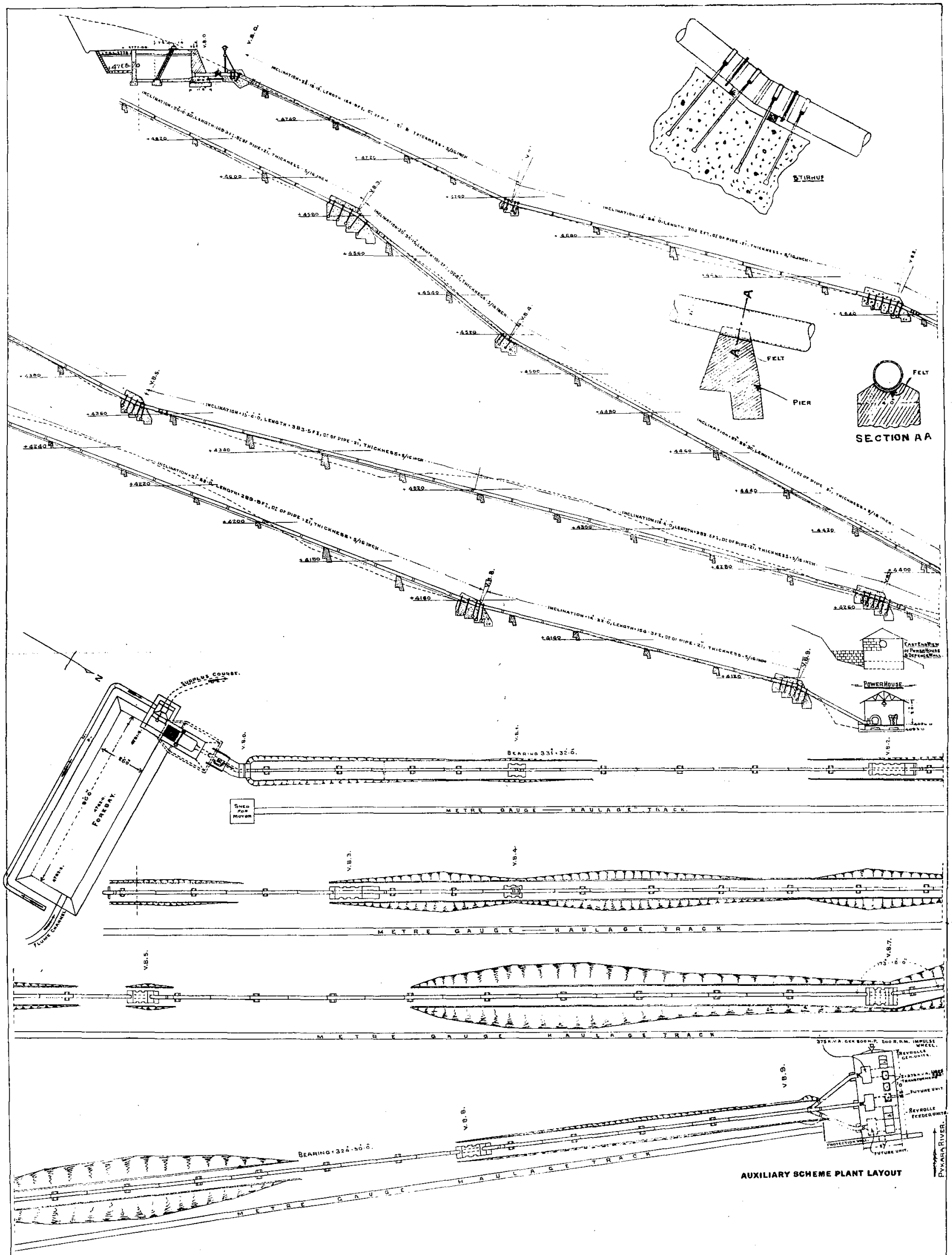


Note:-

To get M.S.D. levels add +1580 to the levels noted in plan

Chief Engineer.

References.	Drawn By.	Department of Hydro-Electric Development, Madras.	No P. 39. / D. 1.
	Traced By, P. Paramasivan.		
Revisions	Checked By, P. N. Iyer.	Pykara H. E. Development.	Scale:- 1" = 20'. Scale:- 1" to 5'.
	Approved By.	Auxiliary Scheme — Forebay	Date:- 19-5-29

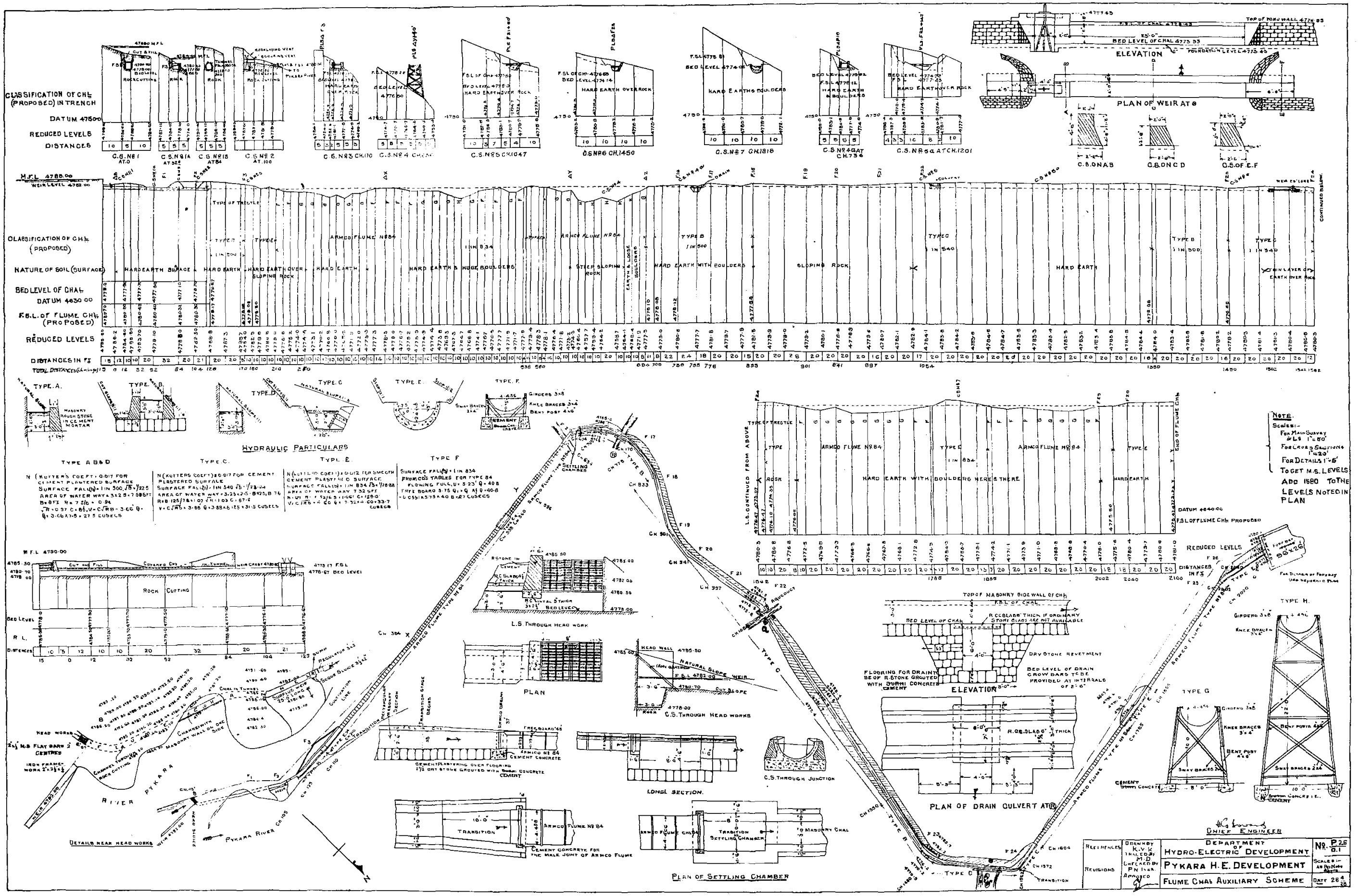


NOTE:— TO GET M.S. LEVELS ADD 1580 TO THE LEVELS NOTED IN PLAN

1. GENERATORS TO BE USED AS SYNCHRONOUS MOTORS AND IRON CLAD SWITCHGEAR TO BE USED LATER FOR MILL CONVERSION
2. TRANSFORMERS TO BE USED ON DISTRIBUTION SYSTEM LATER.
3. IRON CLAD O.C.B. UNITS TO BE INSTALLED IN MAIN POWER HOUSE LATER.
4. IMPULSE WHEEL MAY FIND A MARKET IN SOME ISOLATED TEA OR COFFEE ESTATE.
5. PIPE LINE & VALVES TO BE INSTALLED IN OUTLET WORKS OF DAM.
6. ARMCO FLUME & SLUICE GATES WILL FIND READY MARKET.
7. BUILDING TO BE TAKEN DOWN & TRANSFERRED TO THE PERMANENT CAMP AT PYKARA.

CHIEF ENGINEER

REFERENCES	DRAWN TRACED P PARANDIYAN	DEPARTMENT OF HYDRO-ELECTRIC DEVELOMENT MADRAS	No. P.26 / O.1.
REVISIONS	CHECKED P N IYYA APPROVED	PYKARA H.E. DEVELOPMENT.	SCALE 1 x 20
		AUXILIARY SCHEME PIPE LINE	DATE 30 4 2[illegible]



ELEVATION
PLAN OF WEIR AT B
C.S. ON A B
C.S. ON C D
C.S. OF E F
CLASSIFICATION OF CHL (PROPOSED) IN TRENCH
DATUM 4750.00
REDUCED LEVELS
DISTANCES
C.S. No. 1 AT 0
C.S. No. 1A AT 52
C.S. No. 1B AT 84
C.S. No. 2 AT 100
C.S. No. 3 CH. 110
C.S. No. 4 CH. 410
C.S. No. 5 CH. 1047
C.S. No. 6 CH. 1450
C.S. No. 7 CH. 1818
C.S. No. 4a AT CH. 754
C.S. No. 5a AT CH. 1201
M.F.L. 4788.00
WEIR LEVEL 4787.00
CLASSIFICATION OF CHL (PROPOSED)
NATURE OF SOIL (SURFACE)
BED LEVEL OF CHAL DATUM 4630.00
F.S.L. OF FLUME CHL (PROPOSED)
REDUCED LEVELS
DISTANCES IN FT
TOTAL DISTANCES
ARMCO FLUME No. 84
HARD EARTH
HARD EARTH WITH BOULDERS
SLOPING ROCK
CONTINUED BELOW
TYPE A
TYPE B
TYPE C
TYPE D
TYPE E
TYPE F
HYDRAULIC PARTICULARS
TYPE A B & D
TYPE C
TYPE E
TYPE F
L.S. CONTINUED FROM ABOVE
HARD EARTH WITH BOULDERS HERE & THERE
END OF MASONRY CHL
DATUM 4640.00
F.S.L. OF FLUME CHL PROPOSED
NOTE.
Scales:-
For Main Survey & L.S. 1" = 80'
For Cross Sections 1" = 20'
For Details 1" = 5'
To get M.S. Levels Add 1580 to the Levels noted in Plan
L.S. THROUGH HEAD WORK
PLAN
C.S. THROUGH HEAD WORKS
LONGL SECTION
C.S. THROUGH JUNCTION
PLAN OF SETTLING CHAMBER
ELEVATION
PLAN OF DRAIN CULVERT AT B
TYPE G
TYPE H
DETAILS NEAR HEAD WORKS
RIVER PYKARA
PYKARA RIVER
SETTLING CHAMBER
AQUEDUCT
TRANSITION
ARMCO FLUME No. 84
CHIEF ENGINEER
REFERENCES
REVISIONS
DRAWN BY K.V.K.
TRACED BY M.D.
CHECKED BY P.N. Iyer
APPROVED
DEPARTMENT OF HYDRO-ELECTRIC DEVELOPMENT
PYKARA H.E. DEVELOPMENT
FLUME CHAL AUXILIARY SCHEME
No. P.25

SECTION 5.—AUXILIARY AND CONSTRUCTION PLANT.

During the preparatory construction period it is proposed to use petrol-driven air compressers for riveting and quarrying. When the construction of the main works starts, additional power will be needed.

The installed horse-power on the works is expected to reach 780 with a maximum demand around 400 horse-power.

To provide this power the possibility of a Diesel engine plant was considered, but the more economical method is by means of a small hydro-electric installation described below :—

It is proposed to divert water from the Pykara river just above the main falls, and convey it by an aqueduct to a forebay above the suspension bridge near the Government Cinchona Factory. At this point a fall of 680 feet is available, and it is proposed to develop a maximum of 1,000 horse-power with provision for an ultimate installation of 1,500 horse-power if necessary. This is in excess of the estimated demand for power for use during construction, but it is proposed to utilize the surplus for developing the local power market. About 25 cusecs will be needed for the complete installation, and 15 should be enough at the outset. Should it ever be necessary to supplement the Pykara flow, water could be drawn from the Glen Morgan reservoir. As the forebay was somewhat costly to construct for the required capacity, it was found more economical to design the flume for 27 cusecs.

It is quite an attractive small power development, the total cost working out at Rs. 240 per horse-power. As the whole installation will be in service only for about five years, it is to be so designed that most of the machinery, equipment, and buildings can be utilized again on the permanent works. The net capital expenditure should hence prove very low, and it is hoped to cover all fixed and operating charges out of the revenue derived from the sale of power to outside consumers.

The possibility of electrifying the Nilgiri Railway in the near future has been discussed with the Consulting Engineer to the South Indian Railway, who is of the opinion that it may be found economically feasible to undertake. The necessary power could easily be supplied from this plant with the addition of a third generating unit.

Plans Nos. $\frac{P. 25}{D. 1}$, $\frac{P. 26}{D. 1}$, and $\frac{P. 39}{D. 1}$ show the scheme in some detail, a brief description of which is as follows :—

Diversion wall.—This is formed by filling up in between rocks and boulders to an elevation of 6,362. The cost of the work will be negligible.

Inlet.—This is somewhat similar in design to the main inlet. The crest of the weir is 1·3 feet below the diversion wall and needs a head of approximately one foot to supply 27 cusecs. The canal level is 6,358 feet. This section of the canal—about 100 feet—is covered in, while the inlet is suitably protected with screens. At the far end of the covered section a spillway has been constructed, and a gate is to be installed in the main canal. The design is proof against any floods that are ever likely to occur.

Aqueduct.—Various sections are proposed according to the nature of the ground ; these are shown on the drawing. "*Armco*" flume will be used as much as possible, so that when the installation is no longer required, this part of the flume can be taken down and used elsewhere.

Spillways.—Spillways and scour gates have been provided, at intervals, along the flume.

The forebay together with the aqueduct will provide sufficient water for 35 minutes continuous operation at 20 cusecs. The design is shown on plan No. $\frac{P. 39}{D. 1}$, and includes a spillway and sluice gate. The inlet to the penstock is protected by screens. No gates are proposed, but stop logs can be placed at the entrance to the penstock if necessary. A manually-operated butterfly valve will be installed in the penstock on the outside of the forebay.

Penstock.—There will be one penstock 1,840 feet long, and 21 inches in diameter made of riveted plates in 20 feet lengths. Riveted pipe has been chosen as from enquiries made it would seem that satisfactory contracts could be made with firms in India for the material and erection. It is proposed to use the pipe and valves later for the outlets of the Makurti reservoir. The velocity with two units working at full load is 7 feet per second. The diameter was arrived at after a careful comparison of the conditions for other diameters of penstock. The maximum static head is 678 feet, and loss of head 54 feet. A manifold pipe will be installed in the line near the power-house, to supply two generating units, and a third if necessary. A haulage track and hoist will be constructed alongside the penstock line for use during construction.

Power-house.—This is to be constructed with a steel frame. The roof and walls are to be of corrugated iron sheets with steel window sashes and doors. As the cubical contents of the building per installed K.V.A. is liberal, and suitable ventilation is to be provided, the corrugated iron should not make any difference to the temperature of the building. Both ends of the building will however be of masonry to act as defence walls against abnormal floods. The elevation of the centre of the nozzles will be well above flood level. This type of building was decided upon as it can be erected quickly; when the auxiliary plant is abandoned, the structure can be dismantled, erected again at Pykara, to form part of the permanent camp. The steel frame will therefore be bolted together in the first place and not riveted. No allowance has been made for a travelling crane and the expenses of specially reinforced steel columns have hence been avoided. Whenever any lifting is to be done, a "knockdown" steel frame work and chain block will be available.

Turbines.—Two impulse wheels of 500 horse-power each are proposed with speed around 500 R.P.M. They will be equipped with the usual governing devices and a certain number of spare parts will be provided.

Generators.—Two 375 K.V.A., 0·8 P.F., 400 volt., 50 cycles, 3 phase machines with direct coupled exciters are proposed. It was not considered advisable to specify units of smaller capacity and increase the number as the voltage regulation would have been poor. A construction load consisting of many motor-operated winches and similar equipment, calls for high starting currents, which may cause the voltage of smaller machines to fluctuate between wide limits. These generators will be specially designed so that they can be used later on as synchronous induction motors, for the electrification of some of the larger mills.

Transformers.—Each generator will be connected through a disconnecting switch to a 375 K.V.A. self-cooled transformer which will raise the voltage to 11,000 for local distribution. The alternator-transformer set will be equipped with differential relay protection.

Switchgear.—The high tension side of the transformers will be connected to a 11 K.V. busbar through self-contained iron clad units, each comprising an oil circuit breaker with 50,000 K.V.A. breaking capacity, with minimum time limit overload relay, and the usual indicating instruments. Synchronising will be done on the 11 K.V. side. Four feeders have been allowed for, and each will be controlled by a Reyrolle or similar unit comprising an oil circuit breaker of 75,000 K.V.A. breaking capacity with overload definite time relay, and meters. These feeders are to supply power for construction purposes and to the neighbouring small towns and tea estates. Lightning arrester equipment will be provided on each outgoing feeder.

The transformer and generator control gear will be designed for being used afterwards on the main distribution system, while the Reyrolle units will be transferred to the main Power-House. Panels will be provided for the exciters and for local lighting. There will be no open wiring in the power-house; all wires and leads will be cable.

It will be noticed that almost the whole of the material and equipment can be utilized elsewhere, as soon as there is no further need for the plant. The income from the sale of power is expected to be far in excess of that needed to cover fixed charges and running expenses, so that the actual cost of power used on construction will be very low.

Lighting and power lines.—Certain lines for the distribution of 11,000 volt power to the various parts of the works are provided for in the estimates; also transformers with a low tension network for direct supply to the various motors and lights for the camp and houses.

Immediately the construction of the Pykara scheme is sanctioned orders will be placed for all the materials, machinery and equipment for the Auxiliary Power scheme, and work in the field started.

Roads.—The estimates provide for the reconstruction of sections of the Ootacamund-Pykara Falls road for axle loads up to 6 tons and, if necessary, this road will be taken over from the District Board and maintained during the period of construction by the Pykara construction personnel.

A new road is necessary from Pykara falls to the Auxiliary Plant forebay, and another from Masinigudi to the main power-house site. The Masinigudi-Teppakadu road will need a certain amount of reconstructing. A liberal contingent allowance is included for any contribution which may have to be made to the Mysore State for the use and repair of the Nanjangud-Teppakadu road. This will form the subject of a conference with the engineer responsible for the Mysore State roads at some future date. It is not intended to transport any very heavy loads over this road, and it is very unlikely that the Nilambur-Gudalur-Teppakadu road will be used.

Transportation.—After a study of transportation costs by the various routes and by different means, it is proposed to forward all material and equipment for the hydraulic works and part of the penstocks by rail to Ootacamund. From the railway station to Pykara the transportation will be, as far as possible, by contract. All pieces needed for the power-house and exceeding five tons in weight will also be transported by this route with special equipment, and lowered down the penstock line. Pieces below this weight will be shipped to Nanjangud and hauled by road to Masinigudi, about 52 miles. It has been suggested that even heavy machinery might be sent via Nanjangud. It must be realized that there will probably be only about twenty loads exceeding five tons; to carry these the greater part of this road would have to be repaired, and some five bridges and numerous culverts permanently or temporarily reinforced to stand loads up to 12 tons. It is apparent that this would not be a very economical step.

The haulage railway down the penstock line will have a speed around 200 feet per minute and four relay stations. It is believed that this will provide sufficient capacity for the transportation of men and material. It will be mainly used for the construction of the penstocks but as mentioned before, the heavier pieces of machinery and equipment will also be handled by this means. When it is realized that for the penstocks alone over one thousand pieces will have to be transported, many of these pieces forming single loads by road, the necessity for a very careful study of the transportation problems is apparent.

The cost of transportation and maintenance of equipment is covered in the transport charges for all machinery and material; these are included in the various estimates. The cost of the original transport equipment is allowed for in the estimate for construction plant.

Construction methods.—The hydraulic works do not call for any special construction methods, and the use of machinery and labour-saving devices will be limited. It is believed that the supply of labour will be satisfactory. None of the structures is large enough to need introduction of special construction plant and training of gangs of coolies in new methods. These, if attempted, might result in delays and additional expense. So, as far as possible, construction methods usually adopted in the Public Works Department and to which the workmen are accustomed, will be followed. Cement will be specified for all structures with the possible exception of the buildings. In the writer's opinion it is only on comparatively unimportant works or where the time factor is of no importance that the use of lime and surki mortar can be justified.

A construction schedule is being prepared and will be submitted to the Power Securities Corporation and the South Indian Railway for approval. Once agreed upon, it must be strictly adhered to.